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ASSESSING TECHNOLOGY TRANSFER

by

RICHARD L. LESHER
Assistant Administrator for Technology Utilization

and

GEORGE J. HOWICK
Director, Technology Utilization Division

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Preface

IN AUGUST 1964 Congress authorized the establishment of a National Commission on Technology, Automation, and Economic Progress. As spelled out in Public Law 88–444, the four primary functions of the Commission are to:

(a) identify and assess the past effects and the current and prospective role and pace of technological change;

(b) identify and describe the impact of technological and economic change on production and employment . . . and the social and economic effects on the Nation's economy, manpower, communities, families, social structure, and human values;

(c) define those areas of unmet community and human needs toward which application of the new technologies might most effectively be directed; and

(d) assess the most effective means for channeling new technologies into promising directions, including civilian industries where accelerated technological advancements will yield general benefits, and assess the proper relationship between governmental and private investment in the application of new technologies to large-scale human and community needs.

This publication is an abridgment of a report prepared for the Commission in November 1965, and directing itself primarily toward the fourth of those functions, i.e., assessing effective means of channeling new technologies in promising new directions. It does not recommend any single "most effective means," for too little is known at this time about the complex mechanisms of technology transfer. It does, however, consider such questions as: (1) Is the transfer of technology a worthwhile national goal? (2) Is there sufficient technology available, from federally supported sources, to permit a useful intersectoral transfer effort? (3) Can technology be transferred from one industry to another, one discipline to another, one region to another? (4) What is known about the incentives and barriers to transfer? (5) What mechanisms or channels have been employed to date, and with what success? (6) What are the essential elements, as perceived today, in the most effective methods?

To prepare the original paper, the authors conducted depth interviews with persons in the Government agencies that have technology-transfer and information-dissemination programs. A comprehensive literature search was also conducted. Far too many persons gave generously their time and experience to permit individual acknowledgment, but the authors are deeply indebted to them all for guidance, counsel, specifics, and perspective.

RICHARD L. LESHER
GEORGE J. HOWICK

Washington, D.C.
October 1966

Assessing Technology Transfer

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Conclusions and Recommendations

Devising means of channeling new technologies in promising directions—and bringing about the utilization of new technology for significant purposes other than the immediate use for which it was developed—has become an activity ranking among the most intellectually challenging of our time. It is recommended that Government agencies and private organizations alike encourage talented people from the many disciplines who can contribute to the work.

The transfer and utilization of new technology offer immense opportunity to the Nation. There is widespread agreement among those who have studied the issue that the knowledge resulting from public investment in R. & D. constitutes a major, rapidly increasing, and insufficiently exploited national resource. Its effective use can increase the rate of economic growth, create new employment opportunities, help offset imbalances between regions and industries, aid the international competitive position of U.S. industry, enhance our national prestige, improve the quality of life, and assist significantly in filling unmet human and community needs. It is recommended that more effective use of this technology resource become a national goal established at the highest levels.

Measures exist to show that a considerable portion of the technology resulting from military/space/nuclear work is relevant to needs outside those mission areas. It is recommended that those who can bring about or influence the use of this technology in the civilian economy be alerted to the relevance of the technology.

Traditional means of transferring technology—such as the intersectoral movement of knowledgeable people, corporate diversification, conventional library systems, the college classroom, and the technical journal—while still extremely important, are no longer wholly adequate. This is due, in part, to the sheer volume of new technology being generated, the rapid pace of its discovery, the increased complexity of the economy, and the technological gap between the military/space/nuclear sector and the main body of the economy. It is therefore recommended that complementary mechanisms be devised to aid in the channeling, transfer, and utilization of new technologies from sector to sector, industry to industry, region to region, discipline to discipline, market orientation to market orientation.

It is increasingly apparent that a communications gulf exists, as a derivative of the technology gap, between the principal generators of new knowledge and large bodies of potential users. This is not a simple problem of language, but a complex problem involving attitudes, values, goals, work patterns, orientations, environments, and other variables. This results in a need for intermediaries or couplers who can operate effectively at the interface between knowledge and need, and who can communicate effectively with those at both ends of the pipeline. It is recommended that professional societies, foundations, trade associations, and other groups aid in defining and developing necessary coupling mechanisms and locating and training people who can perform the function, with Government agencies continuing an active role.

Technology transfer is one of many areas in our economy where it is difficult to move programs forward because the responsibility is shared by the private and public sectors. The issue is complicated further by the fact that existing Federal programs to perform the function vary in their level of Government involvement by several orders of magnitude. It is recommended that a national policy be devised spelling out the conditions under which Federal agencies should conduct, foster, or support programs at each of the various levels.

The pressing nature of the problem tends to lead to proposed "solutions" of a sweeping, but impractical, nature. Several times it has been proposed that a "national system" be created. Far too little, it seems obvious, is known at this time to design a single national system, and it is unlikely that this would be the optimum solution in any case. It is recommended that serious and continuing analysis be given to the question, and particularly to the feasibility of designing a national capability made up of a multiplicity of coupled, user-oriented systems, with workable switching devices and the capability to tailor output for specific, but continually changing, groups with common needs or objectives.

Significant benefits can result from the application of technology generated by one Federal agency to the missions of other agencies. It is recommended that interagency efforts be encouraged and fostered, and where practical, that special skills of one agency be employed on an ad hoc basis by other agencies.

Federal expenditures for scientific and technical information are large and increasing. In order to reap the maximum rewards from this investment, there should be as much commonality as can be achieved among information handling systems in their languages, abstracting and indexing approaches, and other points of interlock, consistent with the overriding requirement for each to best serve its particular audience and to continue to advance the state-of-the-art in information handling.

The solution of pressing urban problems, from a technological viewpoint, and the enhancement of economic growth as a result of technological advance, rest on the ability of private companies to innovate. Thus, the focus for any broad-scale program to transfer technology must be the innovative technical community within private industry.

Technical information is a marketable commodity. True transfer programs add value to that information by abstracting, categorizing, separating out the significant, dividing the relevant from the nonrelevant, and by interpretation, analysis, repackaging, and provision of local access. The user of a system should therefore be expected to share in the cost of its operation.

Awesome opportunities for slippage exist at each stage in the processing of technical information. It is recommended that increased attention be devoted to the software aspects of mechanized systems and that special emphasis be given to education in abstracting, indexing, and the design of search strategies.

There is no substitute for the effect of a "personal champion" of new technology. Research should be undertaken to determine the characteristics of such people and the means of locating them. Users of new technology should attempt to find such people within their organizations and place them where they can work toward developing the maximum benefit for their organizations from the technology resource.

New technology has no value until it is recognized. To glean the optimum knowledge from Federal R. & D. programs, it is recommended that all agencies with significant R. & D. budgets establish a means of identifying the new technology they create, inhouse and through contractors and grantees.

New technology has no value until it is used, and it cannot be adapted for use by an organization unaware of its existence. It is recommended that all those involved in programs to channel new technologies in promising directions spend some time on the marketing aspects of the business, communicating to prospective users the vast potential value of the knowledge resource and reacting to the needs of special groups of users by tailoring programs to fit their requirements.

New technology is best transferred intersectorally by those who comprehend it and perceive its secondary applications and ultimate implications. It is therefore recommended that Federal agencies generating significant new technology should perform central roles in bringing about the application of that technology.

Introduction

This year, more than $15 billion in Federal funds will be used to create new knowledge through research and development. We are generating more new knowledge in 1 year than we generated in a full decade less than half a lifespan ago.

In fact, looking upon the last 50,000 years of man's existence in terms of lifespans, the speed of progress—the pace of change—is readily apparent.

Eight hundred lifespans can bridge more than 50,000 years.

But of those 800 people, 650 would have spent their lives in caves or worse; only the last 70 had any truly effective means of communicating with one another; only the last 6 ever saw a printed word or had any real means of measuring heat and cold; only the last 4 could measure time with any precision; only the last 2 used an electric motor; and the vast majority of the items that make up our material world were developed within the lifespan of the 800th person.

Such has been our progress, but we have created equally awesome problems: We send men more than 160 miles above the earth's surface and return them safely, but we kill one another on our highways; we can create a comfortable living environment 300 feet below the surface of the ocean, but we breathe garbage-laden air in our cities.

How much of our available knowledge is really being used for all relevant purposes? How much of our new technology can be translated into improved products and processes to spur economic growth and improve our standard of living?

No answers can be given to such quantitative questions. But this study shows that there is much to be gained—both the quantity and quality of life—from better exploitation of available knowledge.

Technology as a Factor in Economic Growth

While this paper is concerned with means of making new technology available to those who can use it, it seems important first to ask if the benefits of employing new technology warrant an investment in the means of making it available. All indications are that it will.

Only recently have economists devoted much attention to causal relationships in economic growth. But throughout the literature, one can trace the awareness—by economists and policymakers—of the importance of science and technology in economic health.

More recently, economists have attempted to measure the contribution of technology to the rate and volume of economic growth.

Robert M. Solow estimated that of the total increase in U.S. output per man-hour from 1909–49, only one-eighth was due to the increase in capital investment while seven-eighths was due to technological progress.[1]

Solomon Fabricant has found that, during the 1871–1951 period, technological advance accounted for 90 percent of the rise in output per man-hour (versus 10 percent for capital formation).[2]

Benton Mossell, found that (during the 1919–55 period) technological changes accounted for approximately 90 percent of the rise in output per man-hour.[3]

Edwin Mansfield, in a study of innovation and its effect on the growth of individual companies, found that the innovative companies grew much more rapidly (during a 5–10-year period after the innovation occurred) than other firms in their industries. The average growth rate of the innovators was often twice that of the others.[4]

Zvi Griliches asserted that:

> It is clear by almost any conventional method of measurement that productivity increase has been the most important component of economic growth in the United States in recent decades. The growth in productivity in turn can be divided into two parts: (1) The improvement in efficiency due to the elimination

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[1] Solow, Robert M., "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics,* vol. 39 (Aug. 1957), pp. 312–320.

[2] Fabricant, S., "Resources and Output Trends in the United States since 1870," *American Economic Review,* vol. 46 (May 1956).

[3] Mossell, B. F., "Capital Formation and Technological Change in U.S. Manufacturing," *The Review of Economics and Statistics,* vol. 42 (May 1960), pp. 182–88.

[4] *Reviews of Data on Research and Development,* No. 38 (National Science Foundation, Washington, D.C., March 1963). See also: Mansfield, Edwin, "The Expenditures of the Firm on Research and Development," Cowles Foundation Discussion Paper No. 136 (Yale University, 1962).

of various disequilibria; and (2) the expansion of the boundaries of knowledge.[5]

Edward Denison predicts that advances in knowledge will be the most significant stimulus for economic growth during the 1960–80 period.[6]

It is apparent to even the most casual observer that advancing technology has drastically transformed the character of man's activity. A century ago, men and animals provided nearly all the musclepower in industry. Machines supplied about 1 horsepower per production worker. Machines now provide more than 10 times that amount of energy. The farm population, in that time period, has decreased from 8 in 10 to less than 1 in 10, thanks to increased farm mechanization. And since 1860, the average lifespan has jumped from around 40 to around 70 years, owing to medical advances in the prevention and cure of disease and to gains in sanitation and nutrition.

It is clear that the infusion of new technology can speed the rate of economic advance. But the importance of new technology to society cannot be measured solely by its contribution to our gross national product. GNP measures, with limitations, the output of goods and services in the national economic system. But any realistic assessment of economic performance must also consider how that output is distributed, the ability of the system to make the generation of that output personally rewarding, and the environment—or the quality of life—created by the system. GNP does not measure the economic system's performance in terms of giving people what they really want.

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[5] *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Report of the National Bureau of Economic Research (Princeton University Press. 1962).

[6] Denison, Edward, *The Sources of Economic Growth in the United States and the Alternatives Before Us*, Supplementary Paper No. 18 (New York: Committee for Economic Development, 1962).

Much of the benefit of the infusion of new technology into the economy is not reflected in measures of productivity. For example, if technology permits the making of a better product without a corresponding change in production costs, the result is not reflected in statistics of output—but is a decidedly beneficial action.

One approach to the full realization of the benefits of new technology, it appears, would be to arrange for its effects to be more widely felt—to be diffused into more industries, more governmental missions, and more regions of the country. In others words, programs to channel new technologies in useful and satisfying directions can have the effect of notably enhancing the rate of economic growth—though the full effect of such programs would likely not be measured by conventional methods.

Denison has shown that differences in levels of formal education attainment create significant differences in productivity.[7] It follows that differences in practical professional knowledge acquired after completion of formal education can have a similar effect. In other words, the scientist, engineer, or businessman who continued to accumulate new knowledge—via being somehow updated in the latest R. & D. results in his field—would be more productive than the one who was not. If that logical assumption were indeed proved true, then investment (public or private) in programs to identify, evaluate, and utilize new technology would pay significant dividends in productivity improvement at the level of the firm or end user of the technology.

Many studies of the contribution of technology to economic growth have concentrated on the economic impact of major inventions and innova-

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[7] *Ibid.*

tions. But the most important contributions to economic growth may be stimulated by widespread adoption of incremental improvements.

John Jewkes noted that:

> There is no evidence which establishes definitely that technical or economic progress receives greater contributions from the few and rare large advances in knowledge than from the many and frequent smaller improvements. Economically, it might for a period well pay a community to starve its scientific and major technical work and to devote resources to the most thorough and systematic gathering together and exploitation of all the immediate and tiny practical improvements in ways of manufacture and design.[a]

Students of the question see many serious economic and social implications in this situation. Among the difficulties mentioned as growing out of this problem are:

Regional economic imbalances. With the three States of California, New York, and Massachusetts obtaining approximately half of total Federal funds for performance of research and development, there is a tendency for industry in those regions to reach a level of technological sophistication far above that possible in some other States. But if the technology resulting from R. & D. performed in California could readily be channeled into those industries in other areas, the chances for regional imbalances in technological capability would be lessened.

Industry imbalances. The current pattern of R. & D. fund distributing could also tend to create serious interindustry imbalances. For example, consider the machine tool industry. Its technological health is important to the national defense posture and to the ability of other industries to reach high levels of productivity. But nearly every significant new advance in metal cutting and

[a] Jewkes, John, David Sumers, and Richard Stillman, "The Sources of Invention" (St. Martin's Press, New York, 1959).

metal forming has been developed by a firm not traditionally part of that industry. It is argued that a better means must be developed to channel the technical advances made in the aerospace and related industries to the machine tool industry and other basic industries, where such technical advances can be commercialized and in turn contribute to the technical and economic health of still other industries.

Timelag. Enlarging the use of new scientific and technical knowledge, it is argued, would contribute to economic growth by reducing the timelag between discovery of new knowledge and its economic exploitation.

International competitive position. Early and effective utilization of new technology will logically have a beneficial effect on the U.S. balance of payments via increased exports of U.S. goods. This comes about in several ways: (1) Cost reductions enabling U.S. goods to be more price competitive in international markets; (2) new products and product improvements can expand overseas markets; and (3) creation of entire new industries whose output can be sold worldwide (e.g., commercial jet aircraft and computers).

Perhaps none of the specific arguments in themselves make a conclusive case for the fact that channeling of new technologies in promising directions will significantly speed economic growth. But the arguments that have been put forth by various students of the question—when examined in composite—make a formidable case for the theory.

Briefly, the individual arguments are:

- The use of new technology can reduce production costs, thus increasing productivity.

- The use of new technology can sometimes permit the output of a wider range of customer-satisfying products and services without a corresponding increase in capital investment, thus raising the return on invested capital and/or permitting price reductions.

- The use of new technology can shorten the timelag between the development of new knowledge and its widespread applications, thus spurring the growth process.
- The use of new technology can enhance the international competitive position of U.S. industry, thus improving our balance of trade.
- The use of new technology in the civilian sector—because such new technology will generally be adapted and coupled with other technology to create another sheath of new technology—can in turn provide new technological input to Government programs in space and defense, thus enhancing our defense posture and aiding our international prestige.
- The use of new technology in some areas—medical research, urban design, mass transportation, to name a few—can improve the quality of life.
- The use of technology in one sector that was originated in another can help to provide a balance in the economy in terms of technological capability, thus avoiding problems that might—though would not necessarily—be created by the concentration of research and development effort in a relatively few companies within a few industries in a few geographical regions.
- The use of new technology can stimulate the production of new products, thus creating new jobs.
- The use of new technology can reduce the cost (and, hopefully, the price) of producing existing products, thus freeing purchasing power for the acquisition of other products, creating additional jobs in those areas.

Is Technology Available for Transfer and Utilization?

It seems clear that more rapid and more widespread use of available new knowledge would have many benefits. It would, for example, tend to speed the national rate of economic growth, smooth out regional and interindustry imbalances, and enhance the U.S. position in international trade.

But is new technology available for use? And—importantly—is the new technology relevant to the needs of society? This section is devoted to answering those questions.

Sources of New Technology. This paper emphasizes new technology developed as a result of Federal programs, since only that portion of new technology is sufficiently in the public domain to be made available for wide-spread use via channeling and coupling mechanisms.

The Federal Government is currently supporting research and development programs at an annual rate of more than $15 billion. That is double the outlay in 1960, triple the amount expended in 1958, and 15 times the outlay in 1950.

Since 1940, Federal spending for research and development has risen at an average annual rate of nearly 20 percent, from $74 million in 1940 to $15.2 billion in 1965.

For every $100 spent by the Federal Government this year, approximately $15 will be spent for research and development. That compares with $10 in 1960, $5 in 1955, and $1 in the mid-1940's.

Federal spending for R. & D. is also increasing far more rapidly than total economic activity. Before World War II, federally supported R. & D. was equivalent to a few tenths of 1 percent of the gross national product. By 1953, it equaled 1.4 percent of GNP and is now close to 3 percent.

Three agencies—Department of Defense, National Aeronautics and Space Administration, and Atomic Energy Commission—account for nearly 90 percent of Federal R. & D. spending. The nature of the missions of these agencies demands that the funds be spent across the full spectrum of R. & D.—from the most basic type of research to the most applied kind of development (which is really closely akin to plant engineering). Table 1 shows the sources of Federal R. & D. funding by agency.*

TABLE 1. BUDGET EXPENDITURES FOR RESEARCH AND DEVELOPMENT, 1954–66 (IN MILLIONS OF DOLLARS)

Fiscal year	DOD [1]	NASA [2]	AEC	D/HEW	NSF	Other	Total
1954	2,487	90	383	63	4	121	3,148
1955	2,630	74	385	70	9	140	3,308
1956	2,639	71	474	86	15	161	3,446
1957	3,371	76	657	144	31	183	4,462
1958	3,664	89	804	180	33	220	4,990
1959	4,183	145	877	253	51	293	5,803
1960	5,654	401	986	324	58	315	7,738
1961	6,618	744	1,111	374	77	356	9,278
1962	6,812	1,251	1,284	512	105	409	10,373
1963	6,849	2,540	1,335	632	142	490	11,988
1964	7,516	4,171	1,503	791	197	496	14,674
1965	7,222	4,900	1,569	801	208	655	15,355
1966	6,880	5,100	1,557	936	266	706	15,445

[1] Includes civil functions.
[2] National Advisory Committee for Aeronautics prior to 1958.

SOURCE: National Science Foundation.

In the last 10 years, Federal funds have paid for more than $88 billion worth of R. & D.—more than 60 percent of it as a result of defense requirements. More recently, R. & D. in support of space exploration has risen to a place of importance nearly equal to that of the defense realm. And

*The reader is also referred to the statistics on Government expenditures for research and development, as compiled by the National Science Foundation and published in *Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1964, 1965, and 1966*, vol. XIV, NSF Publication No.: NSF 65–19, July 1965.

continued expansion of R. & D. by the Department of Health, Education, and Welfare is bringing that agency into a funding position as important as the Atomic Energy Commission was in 1960.

Most R. & D. continues to be performed by private industry, with the bulk of new technology generated within profitmaking corporations (see fig. 1). Thus any effective program aimed at channeling new technologies in promising directions—or any program aimed at finding secondary uses for the results of federally funded R. & D.—would have to incorporate some means of identifying and reporting new concepts, inventions, innovations, and other useful information generated within a diversity of corporate entities. The implications of this requirement will be discussed later.

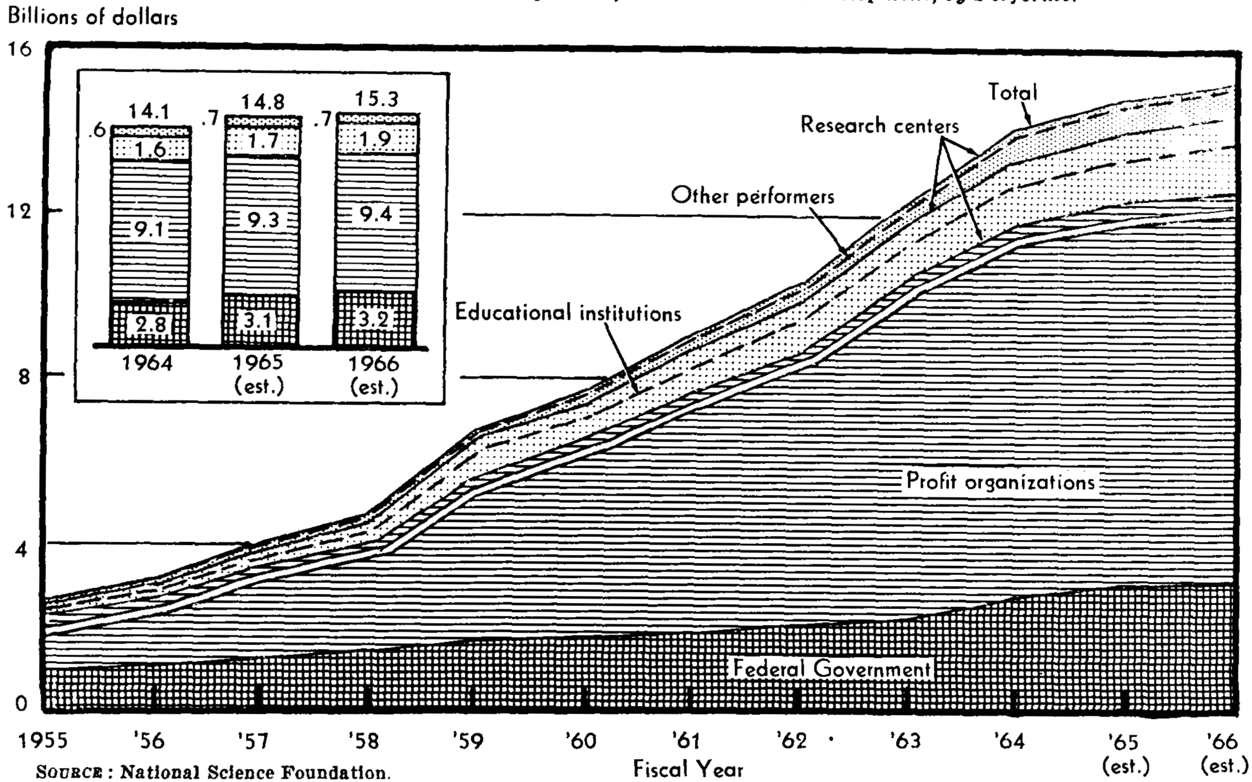
There is no indication that Federal funding for R. & D. has reached a peak; in fact, all signs point to continued growth of such outlays. While no rapid growth in Federal spending for defense R. & D. is likely, continued expansion in such areas as health, space, and socioeconomic areas seems likely.

One writer suggests that, by 1995, if present trends continue, there will be 8 times as much scientific and technical information available as exists today.[9] Numerous measures exist to show the volume of new technology being generated via U.S. Government programs. Among the measures are:

- Around half the scientists and about one-third the engineers in the United States are currently employed in research and development or its administration and management (the others teach, work in production, etc.).[10]

[9] Hines, William, "A Scientific Data Moratorium?," *Washington Evening Star*, Apr. 27, 1965.
[10] Rosenbloom, Richard S., "Technology Transfer—Process and Policy," National Planning Association Report No. 62, July 1965.

FIGURE 1. *Trends in Federal Obligations for Research and Development, by Performer*



SOURCE: National Science Foundation.

• The United States currently accumulates more than 100,000 Government reports each year, plus 450,000 articles and countless books and papers. On a worldwide basis, the literature is growing at the rate of an estimated 60 million pages per year.[11]

• On December 31, 1962, the U.S. Government owned 13,671 patents and the number was increasing at the rate of about 1,900 annually. A survey disclosed that around 10 percent of the inventions assigned to the Government also reached a stage of commercial utility.[12]

• In January 1963, NASA reported that its work, conducted both in Government laboratories and private facilities, had led to 786 inventions. By August 1964, the number had increased to 2,500; and by May 1965, that number had doubled to 5,000.

But volume of technology alone is an insufficient basis for justification of an effort to channel technology into the civilian economy—although it is one necessary indicator. As H. G. Barnett pointed out:

> The size and complexity of the cultural inventory that is available to an innovator establishes limits within which he must function. The state of knowledge and the degree of its elaboration during his day, the range and kind of artifacts, techniques, and instruments that he can use, make some new developments possible and others impossible. The mere accumulation of things and ideas provides more material with which to work. A sizable inventory allows for more new combinations and permits more different avenues of approach and problem solution than does a small one.[13]

It is clear that Federal support of R. & D. has in recent years generated "a sizable inventory." But

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[11] Watson, Thomas J., Jr., testimony before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, U.S. House of Representatives, May, July, and September 1963.

[12] Holman, Mary A., "Government Research and Development Inventions—A New Resource?," *Land Economics*, August 1965.

[13] Barnett, H. G., *Innovation: The Basis of Cultural Change* (McGraw-Hill Book Co., New York, 1953).

how relevant to the needs of society are the items of knowledge stocked in that inventory?

Certainly, man's capability to accumulate and retrieve information has always paced his progress. But the sheer volume of information available today—unless properly managed in an organized system that permits the right information to be found by the right person at the right time—may be tending to inhibit progress.

The man who has been forced, in the course of his work, to seek out that available information which is relevant to his objective will readily attest to the maze of paths—most of them unmarked—which he must follow to uncover even a small portion of the information that is potentially relevant. And in the process, he is likely to be forced to sift through a great deal of information that is not relevant.

While significant strides in information management have been made in the last 5 years by such groups as COSATI, AEC, NASA's Scientific and Technical Information Division, the Science Information Exchange, the Library of Congress, the Defense Documentation Center, and others (including a number of nongovernmental organizations), the state of the art in information retrieval (as distinct from document retrieval) is still woefully inadequate.

The size of the inventory of information in a quantitative sense is best illustrated by pointing to some standard measures of information volume:

- The last issue of the *World Bibliography of Bibliographies* lists more than 100,000 separately collated volumes of bibliographies.

- More than 30,000 scientific and technical conferences are held each year throughout the world. Many publish proceedings.

- There are nearly 1,900 independent abstracting and indexing service organizations dealing in scientific and technical fields throughout the world, with 365 of them in the United States.
- *Scientific and Technical Aerospace Reports* (STAR), the NASA indexing guide to the world's unpublished reports in aerospace, carries about 30,000 new listings annually. The companion journal, *International Aerospace Abstracts*, which lists published articles in the aerospace field, contains about 28,000 new entries annually.
- *Technical Abstracts Bulletin* (TAB), the listing of new accessions in the Defense Documentation Center (DDC), carries nearly 1,000 new entries each month.
- In the last 12 months, the Science Information Exchange added 100,000 records of ongoing research tasks to its information bank.
- The National Science Foundation lists Federal obligations for scientific and technical information for fiscal year 1966 at $258,673,000. However, total Federal expenditures for scientific and technical information processing are far greater. For example, NSF reports total obligations of the AEC for this type of work at $5,474,000. The AEC, however, estimates its total expenditures in this area for fiscal year 1966 at $28,842,000. Of the total, formal budget items account for only $1,522,000.

Obviously, the volume of Government-generated scientific and technical information has reached the stage where, without systematic information management and dissemination, the odds that an interested scientist and engineer could obtain needed information would be very low indeed.

The question then becomes: Is the available information sufficiently relevant to the needs of society to justify investment—either public or private—in the means of making the right information available to the right person at the right time?

Is Government-Generated Technology Relevant?

It is obvious to even the casual observer that an extremely large technological base has been generated by the research and development programs of the Federal Government, principally the DOD, AEC, and NASA. But does this knowledge have any value in the context of meeting community and human needs?

Critics of existing programs to transfer technology from one industry or one discipline to another generally state the proposition this way: "If we spent billions of dollars to develop better home appliances, would we, in the process, get a man to the moon or build a better ballistic missile?"

The answer, obviously, is "no." But the wrong question has been asked.

Rephrasing the question to recognize the nature of R. & D. efforts of NASA, AEC, and DOD, we would ask: "If we spent billions of dollars in research and development in every scientific and engineering discipline, is it likely that the new knowledge thereby generated might find wide applicability in helping to meet the problems of an industrialized society?"

Now the answer, obviously, is "yes."

Of course, if major R. & D. programs were initiated specifically to seek solutions to given problems outside the space/defense/nuclear realm, the odds in favor of generating specifically useful new knowledge would very likely increase.

But the priorities have been assigned. The Nation is already committed to major R. & D. in support of defense, space exploration, and utilization of nuclear energy. For the purposes of this paper, then, the question is whether the results of that R. & D. might have secondary utility; whether the problems and objectives outside the space/defense/nuclear realm in any way overlap those within that realm.

Certainly, there is overlap.

Is the overlap sufficient to justify an investment—public or private—in a means of funneling that relevant knowledge to secondary uses?

The authors believe available information is too meager for a definitive answer. But on the basis of experience in technology transfer thus far, there appears to be sufficient potential for secondary application to justify substantial investment in efforts to find a clear answer.

There are numerous indications that new technologies being generated with public funds in support of defense/space/nuclear missions have substantial value in secondary applications. Among those indications are:

- NASA/DOD/AEC, in composite, are conducting or sponsoring research in every scientific and engineering discipline; this means that the results of this research can be applied to meet a wide range of community and human needs.
- The small—and extremely youthful—programs that have been established by NASA, AEC, and the Department of Commerce to channel scientific and technical information to private industry and other organizations have already borne some fruit.
- Those who have studied the question have concluded that the results of Government-sponsored R. & D. do have potential relevance in secondary areas.

• The transfer of knowledge—from industry to industry, discipline to discipline, region to region, country to country, culture to culture, and generation to generation—has been a continuing process throughout the history of man. Technology transfer should not then be considered a new and untried concept. History proves its workability. However, the current concern is to speed the transfer process—to shorten the time gap between the discovery of new knowledge and its application across a broad spectrum. A body of knowledge on how to accomplish this transfer process has not yet been developed and assimilated. (This is discussed in greater detail later.)

The breadth of research and technological development being carried forward today by the Federal Government is partially indicated by the broad classifications of grants and research contracts NASA sponsors in universities and other nonprofit institutions: Physical sciencies, engineering sciences, cosmological sciences, socioeconomic studies, scientific investigations in space, satellite applications investigations, vehicle systems technology, supporting activities, space operations technology, space propulsion technology, flight medicine and biology, basic medical and behaviorial sciences, and space biology.

In addition to the vast amount of new scientific and technical knowledge being generated in their programs, AEC, NASA, and DOD have—by necessity—developed a number of new management methods and analytical techniques that have applicability in other areas.

One such concept was spelled out by John Paul Stapp:

> **Behind the headlines that hailed the success of each Project Mercury orbital flight was an organized effort actively involving more than 19,000 people with all degrees of training and skill, deployed in 16 ground**

> stations around the world, sailing the oceans in 28 ships and flying in more than two score aircraft. Never before in human history have so many people so widely separated, worked together on a single scientific experiment. A revolution in scientific research and technological development, this highly organized systems approach has opened a new phase in man's development. The beginning of this scientific and technological renaissance merits more detailed consideration, particularly in its projected lines of development and future implications for the human race.[14]

Systems analysis has direct relevance to such problems as design of mass transit systems, crime prevention, waste disposal, pollution control, regional resources development, and other areas of human needs where the important influences (political, social, and economic) are fragmented, the variables are many and their relation to one another is dynamic, and the technological requirements cover a broad spectrum.

A single innovation, of course, can have relevance in a multiplicity of secondary applications. For example, it seems reasonable that work NASA, AEC, and DOD have done in developing manipulators and devices to extend human physical capabilities might be applicable, to varying degrees, in each of five areas: (1) prosthetic devices; (2) material handling equipment for hot or difficult environments; (3) in ocean engineering and "underwater plumbing"; (4) for automated industrial handling situations; and (5) for small particle manipulation in laboratories and medical testing facilities.

It seems clear that a primary product of the space, nuclear, and defense programs is new knowledge—not just in a few fields but in every important discipline. It also seems clear that a significant portion of that new knowledge can be applied in a multiplicity of other areas. Certainly,

[14] Stapp, John Paul, "The World Science Will Create." *Nation's Business*, January 1965

there is sufficient potential relevance to justify an investment in experimental efforts to attempt to match available knowledge to unmet human needs.

Why Technology Transfer?

Apollonius of Perga discovered conic sections in the third century B.C. They were applied to problems of engineering in the 17th century. Chlorinated diphenylethane was synthesized in 1874 but its value as an insecticide (DDT) was not recognized until 1939.[15] An English patent for a "machine for transcribing and printing letters" was issued in 1714. Not until 150 years later—when Remington bought the patents of Latham Scholes—did the typewriter become commercially available.

These examples illustrate the generally experienced timelag between the discovery of new knowledge or articulation of a new concept and its practical application.

Even with a modern climate that permits provision of some Government development funds and an available defense market, there is a notable time lag. For example, it was 6 years from the invention of the transistor to the commercialization of the first transistorized amplifier.

That there should be timelags is natural. Technology does not spring forth in full bloom from the genius of a single discipline or single generation. It moves forward step by step, building on experience, drawing from a multiplicity of individual endeavors and growing steadily more complex, drawing its strength and applicability from an ever-widening range of human skills and an ever-expanding pool of scientific knowledge. Occa-

[15] Dryden, Hugh L., "Interaction Between Space Exploration, Science, and Technology," Speech before the Twin Cities Section of the American Institute of Aeronautics and Astronautics, Minneapolis, Mar. 11, 1965.

sionally, several of technology's life sources converge, resulting in a quantum jump.

But in a society as complex as ours, there are considerable elements of luck and coincidence in the meeting of the producer of new knowledge with the potential user. But to rely on mere chance to bring about utilization of new knowledge would seem to be a most inefficient means of obtaining the maximum return on our large national investment in research and development.

Since early and widespread use of new technology can provide numerous national benefits, it seems in the national interest to effect means of shortening the time gap between the discovery of new knowledge and its use. To do that requires systematizing communication between those who generate new technology and those who can apply it to meeting unmet human needs.

And in a society structured such as ours—a structure that encourages increased specialization—traditional means of communicating no longer suffice. When new knowledge was generated in smaller amounts and fewer fields, the professional journal provided an admirable means of communicating it. When our industrial structure was less complex, the trade magazine provides a channel for communication of comprehensive information within industry. But specialization within disciplines and fragmentation of manufacturing activities have not only made it increasingly difficult to communicate across industry and disciplinary lines—it has become extremely difficult to communicate among fields of specialization within a single industry or discipline.

And just as one innovation or bit of new knowledge can have applicability in numerous areas so also the development of a new device or system may require inputs of knowledge from a multiplicity of endeavors. Knowledge is not provincial—but people sometimes tend to be. While new technology may have utility in diverse areas, it is likely not to be recognized unless deliberately brought to the attention of innovative people working in those areas, in an understandable form, and at a time when it can be given sufficient evaluative attention.

Because a capability exists does not mean it will be used. When Baird called on the Marconi Co., he was told they could find no reason to be interested in television. Optimum utilization of new knowledge will not take place as a natural process.

The discoveries of extreme magnitude, those that lead to the creation of whole new industries, for example, have sufficient inherent force to bring about their own exploitation. Like the gold coin in the coal bin, they are easily distinguished. But the incremental improvements in technology, which individually have seemingly lesser significance but which in composite underpin our industrial might, are less easily brought to the attention of all who can use them. It seems clear that any mechanism created to transfer technology should devote some emphasis to identifying and communicating incremental advances.

It is also apparent that only a relatively small amount of new technology will be rapidly transferred and utilized for secondary purposes without the existence of mechanisms specifically created to perform that function.

Or could the generators of the new technology themselves effect rapid and widespread utilization of that technology? The answer appears to be "no." For one thing, not all of them have either the skills or the inclination to bring about the application of that knowledge. Also, many of the generators are located—both geographically and in terms of professional and market orientation—some distance from the focal points of effective utilization. As James Webb pointed out:

> People performing the actual work in the NASA centers and in the plants of NASA contractors are in the best position to recognize new departures in technology and techniques and to indicate the areas of potential application. But we must still rely on the business community to supply the "profile of industrial or consumer needs." [16]

The situation is aggravated by the fact that Federal funds for research and development are heavily concentrated among a relatively small number of organizations within a few industries concentrated in a few geographical regions. If the generators of new technology were encouraged to bring about its commercial utilization without the assistance of disseminators deployed geographically and industrially, the tendency would be to accentuate whatever regional and interindustry economic imbalances are brought about by the initial concentration of R. & D. performance.

Obviously an effective means of spreading new scientific and technical knowledge is through the migration of people possessing such knowledge. In the 16th, 17th, and 18th centuries, the movement of large groups of people was, in fact, the mechanism by which the diffusion of new technology took place. But the rate of diffusion was painfully slow.

At least 35 years after Abraham Darby had successfully burned coke in his iron-smelting blast furnaces, for example, many English smelters were under the impression that only wood could be used. Frenchmen first melted glass in coal furnaces almost a century after an English innovator had done so, and they acquired the secret of making

[16] In *Business Horizons* (Indiana University), fall 1963.

flint or lead from the English after a lag of more than a century and a half.

Historically, the diffusion of technology by the mass movement of informed people was obviously effective. Equally obvious, it was slow.

Any modern governmental atempt to encourage mass movement of skilled technologists across regional and industry lines would seem to be politically untenable.

But the generators of new scientific knowledge and technological advances must cooperate in any program to channel new knowledge to its points of potential use. It is in their best professional interests to do so.

The case has been stated in the famous Weinberg Report:

> Transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, Government agencies—must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself. The technical community generally must devote a larger share than heretofore of its time and resources to the discriminating management of the ever-increasing technical record. Doing less will lead to fragmented and ineffective science and technology.[17]

The scientist or engineer working in the defense/space/nuclear community has an additional motivation for aiding in the technology transfer process. The civilian applier of his principles and techniques may, in the process of application, develop additional technology of value to the defense/space/nuclear community.

That point was well made by H. Roy Chope of Industrial Nucleonics Corp.:

> Techniques and products which have been invented and created for industrial processes in turn provide

[17] *Science, Government, and Information*, Report of the President's Science Advisory Committee, Jan. 10, 1963.

unique solutions to defense or space problems. Extension of this self-funded R. & D. has now been applied to (1) precision mission tracking; (2) measurement of space radiation; (3) measurement of cryogenic fuels in missiles; and (4) guiding aircraft and helicopters.[18]

Hence, a full circle has been made. A federally created technology (nuclear technology) was further developed and applied to peaceful purposes with private funds. The extension of the peaceful applications then provided new space uses which may not have been dreamed of by the practitioners of the original technology.

The point is clearly stated by Robert A. Solo: "The value of information increases directly in proportion to the speed and breadth of its dissemination."[19]

It might be useful to think in terms of "value added by transfer," much in the same sense as we recognize value added by transportation, communication (publishing, broadcasting, etc.), and retailing. Certainly, information has no value to a potential user unless he is aware of its existence. Further, its value increases as the information is assembled and delivered in terms of the user's language, interests, outlook, points of reference, set of values, and experience. And when the information is combined with other information that complements and supplements it—and the full package is delivered rapidly and in a meaningful form (related to the needs and objectives of the potential user), its value increases still more.

One measure of the economic value of having the right information available for the relevant purposes at the opportune time has been made by

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[18] Testimony before the Senate Commerce Committee on June 10, 1965, in support of the State Technical Services Act of 1965.
[19] Solo, *op. cit.*

Allen and Andrien.[20] They found, in studying four Government-funded, parallel, R. & D. projects, that between 13 and 14 percent of total time spent by the teams was devoted to information gathering.

It seems clear that numerous significant economic and social benefits could be derived if mechanisms could be developed to effectively channel new technologies to the points where they could be applied to public benefit.

The Transfer Process

Commercial utilization of Government-generated technology is a very old story indeed. About 3000 B.C., Sumerian metal smiths saw how a new weapon, the ceremonial battle mace, made the royal bodyguards invincible against their foes. But history indicates it was more than a century before the religious mystique which surrounded the ornamentation and design could be discarded and someone was able to abstract the essential concept: Namely, that a long handle with a bronze head enabled the warrier to smite his enemy harder than the foe could strike back with his stone hand axe. At that point—the "eureka" point in the transfer process—bronze hammers with long handles were introduced to replace hand-held stones for metalworking.[21]

Rosenbloom cites other examples: Food canning was first developed to preserve supplies for Napoleon's army. The electronic computer was invented and improved in a World War II military

[20] Allen, Thomas J., and Maurice P. Andrien, Jr., "Time Allocation Among Three Technical Information Channels by R&D Engineers," Report on an MIT research program in the management of science and technology under NASA and NSF grants, August 1965.

[21] Gadberry, Howard M., "The Need to Borrow Ideas from Other Industries," paper presented at the Valve Technology Seminar, Midwest Research Institute, Kansas City, Mo., Oct. 21, 1965.

project.[22] These were cases of "spinoff" and "fall-out." The transfer occurred largely by chance and seemed to take place in a short time interval only in the cases of extremely significant advances in technology—advances of the importance of the computer and food preservation. "The modern temper," says Rosenbloom "seems to demand more rapid evidence of civilian benefits." [23]

As has been indicated, that demand stems largely from increased concern with spurring economic growth coupled with a growing awareness that Government-generated technology can be applied to civilian needs. In so doing, both the rate of economic and growth and the quality of life can be raised. Increased governmental concern with creation of jobs also contributes to the demand.

The process by which the transfer of technology occurs can be simply stated:

> Technology utilization . . . involves the use of technology developed for one purpose to fulfill a need elsewhere. It requires: (1) The knowledge that an advance has occurred in one field; (2) the recognition of its significance in a different field; and (3) the capability to make the required adaptations.[24]

The effective channeling of new technologies, then, demands more than document dissemination, and even more than communication of information from one point to another. For the assumption is that knowledge will not only be transferred; it will be utilized. The process, it is hoped, will take place over a short timespan with resulting significant benefits.

Therefore,

> a change of approach must be in the offing. A change from an approach that views the transmission of the results of space/military research into industrial ap-

[22] Rosenbloom, Richard S., "Technology Transfer-Process and Policy," National Planning Association Report No. 62, July 1965.
[23] *Ibid.*
[24] *Transference of Non-Nuclear Technology to Industry, op. cit.*

plication as a happy instance of spillover to one that views it as part of an immensely difficult task of social engineering.[25]

Clearly, no one transfer technique will be suitable for technology of such variety as that being federally generated in the second half of the 20th century.

In an early study of the NASA technology untilization program, the Denver Research Institute noted six types of contribution to the commercial sector: (1) Simulation of basic and applied research; (2) development of new or improved processes or techniques; (3) improvement of existing processes; (4) increased availability of materials, testing equipment, and laboratory equipment; (5) development of new products; and (6) cost reduction.[26]

Sumner Myers has pointed to a more fundamental—and seemingly very significant—type of transfer. He sees such activities as the space program setting new standards of achievement for the entire technical community. He asserts that "the space program may be stimulating the process of technological innovation by changing professional norms and general attitudes," and suggests that "the very existence of the space program as a model of technological achievement may prove more important to the economy than either the multiplier effect of its investment or the spillover of its technology." He points out that "people are influenced by and tend to accept as their wants those goals and values shared by their reference groups. Space scientists and engineers are a reference group for industry's staff professionals."[27]

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[25] Solow, Robert A., "Gearing Military Research and Development to Economic Growth," *Harvard Business Review*, November–December 1962.

[26] Denver Research Institute, *The Commercial Application Missile/Space Technology*, September 1963.

[27] In *The Impact of the U.S. Civilian Space Program on the U.S. Domestic Economy*, op. cit.

The space program and, to a lesser degree, the atomic energy program above established a new environment for innovation. This is important, for the climate must be conducive to entrepreneurship if any technology transfer program is to be effective. The innovator, or changemaker, must be accepted—even encouraged—by society if new concepts are to be exploited in the areas where they have the most promising potential.

Even with the right climate, transfer of technology is difficult. While a great deal has been learned from experimental programs conducted by AEC, NASA, SBA, the Department of Commerce, and others, these programs have not covered a very broad spectrum of transfer techniques and channeling mechanisms in relation to the number that might be usefully attempted.

For example, little has been done to effectively foster the utilization, in the civilian economy, of the methods and concepts used to solve military/space problems. David Allison and others have suggested:

> The most important derivative of this [military/space] R. & D. effort is likely to be a new ability to solve problems. Not strictly technical problems, but those involving a mix of components: Technical, managerial, psychological, social, political. If this is true, then we are unwise to watch for spunoff gadgets. Instead, we must develop the means and the wisdom to transfer an intangible.[28]

Some of the problem-solving ability has been transferred, of course, in the process of transferring items of technology. Most such transfer demands some degree (often large) of adaptation on the part of the receiver of the technology. At that point, there is often intensive communication between the purveyor of the technology and its recipient. In the process, the recipient gains addi-

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[28] Allison, David, "Civilian Technology Lag," *International Science and Technology,* December 1963.

tional insight into the problem-solving and managerial concepts employed by the technology generators.

Sumner Myers takes a similar view:

> **The NASA experimental programs often involve firms that would not ordinarily seek out technical help of any kind. Some interesting results have emerged through this process. These firms have had some of their problems solved—often with nonspace information. They have also been shown that they have solvable problems they didn't know they had. The NASA program also provides a good setting for serendipity. For example, one R. & D. manager—after declaring in no uncertain terms that he couldn't use any of the space technology offered his firm—went on to relate how one of the men he met at a NASA-sponsored conference led him to the solution of a problem that had been bothering him for years. One is reminded that to discover anything you've got to be looking for something. The various transfer programs get people looking for something. This may not seem to be an efficient way to transfer R. & D. information but as yet no one knows how to organize the information-innovation linkage more effectively.[20]**

Significant transfer simply seldom occurs in the sense that a piece of hardware developed for military/space/nuclear use can be transplanted intact to another application. More often, it occurs by imitation or analogy.

Because effective transfer demands degrees of imitation, of concept displacement, of "imagineering," "adaptioneering," innovating, knowledge association, and extrapolation—because it is a process to which many diverse disciplines can contribute—and because it demands hard work on the part of both purveyor and receiver for its effectiveness, there are obvious barriers to its acceptance. Likewise, incentives are required.

"The real barriers," in the words of Dr. Charles Kimball, "are neither financial nor technical. The barriers are outdated institutional practice, lack of

[20] From *The Impact of the U.S. Civilian Space Program on the U.S. Domestic Economy*, Report of the National Planning Association, July 1965.

entrepreneurship, and of reluctance to accept new ideas and new practices." He sees barriers to the transfer of technology in four major areas: (1) Within corporate management—an unwillingness to take risks, the absence of adequate mechanisms to deal with all the implications of new products and new processes, an unwillingness to render existing plant and organization obsolete by adoption of the new, a concentration on the short term rather than the long term, and lack of knowledge of the Government sources of new technology; (2) within the scientific community—the Ph. D. who cannot communicate his findings or who has little economic understanding or drive, the inability to distinguish between the transfer of information and the transfer of documents, the confusion between publication and communication, the orientation of some scientists who seem to regard research as a special privileged way of life, and the scientist's inadequate appreciation of management's skills and functions; (3) in institutional factors—the lack of rapport between industry and universities, the unwillingness of some academics to relate their research to the needs of industry, the geographic separation of the generators of new knowledge from those who could employ it; (4) within the human mind itself—creativity is generally thought of as an essentially individual endeavor but American society has moved in such a way that most things are done in groups. We have not yet learned how to provide the climate that fosters creativity, and there is a need for more people to become "innovation prone." [30]

Another compilation of the barriers to utilization of new technology frequently encountered in private companies has been made by Philip

[30] Kimball, *op. cit.*

Wright.[31] The barriers were brought to light when Mr. Wright invited companies being offered new NASA technology to state their views about the difficulties involved in the effective transfer of new technology for the purposes of its commercial utilization in industry. The barriers he cites are:

- **The discouraging effect of abortive reviewing of technical information.**
- **Difficulties of evaluating advantage.**
- **Difficulties of assimilation.**
- **Inhibiting effects of companies' new-idea receptial procedures.**
- **Cheerless effect of the high cost of evaluation.**
- **Frustration owing to delays in response to questions.**
- **The impediment of the difficulties of locating.**
- **Adverse effects of inadequate disclosures.**
- **Adverse results of unfavorable economics.**
- **Barriers owing to educational deficiencies.**
- **The obstructing consequences of inadequate finances.**
- **Adverse influence of government policies.**
- **Obstructions owing to impractical nature of innovations.**
- **Difficulties owing to inappropriate orientation of the presentation of technical information.**
- **Discouraging effects of limited applications.**
- **Inhibiting effects of the absence of information about applications.**

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[31] In a report to the NASA Office of Technology Utilization on activities of the Office of Industrial Applications at the University of Maryland, a NASA regional dissemination center.

- **Hampering situations created by company disinterest in nonexclusive licensing.**
- **Adverse effects of inability to devote time to evaluation.**
- **Deterrent effect of obsolescence.**
- **Impending outcome of weak patents.**
- **Handicaps due to poor communications.**
- **Deterrent effect of proprietary design ownership.**
- **Obstructing impact of security regulations.**
- **Preventative effects of fear of lawsuits.**

The findings of these and other investigators point up the importance of the social environment in acting as a stimulus or barrier to innovation. The problem must be recognized, or the objective defined, or the goal established if innovation is to be applied without considerable suasion. All the technology necessary to providing the optimum means of controlling air pollution can be available but it is not likely to be applied until society recognizes air pollution as a major problem; people communicate their desire to have the problem solved to those who can influence action; those who are influential recognize the availability of the technology; the economics are found to be permissive; and the balance of power among those who influence the decision swings in favor of an early and effective solution to the problem.

That is, of course, a gross simplification of an extremely complex and dynamic situation. But the central point needs emphasis: The specific social environment must be receptive—and preferably active—for technology to be effectively transferred and applied.

From the foregoing, four conclusions can be stated:

(1) For technology to be effectively transferred, the climate must be receptive to innovation and change. Thanks partially to the space program having become widely accepted as a standard for achievement or a reference point for scientific and technological excellence, such a climate does exist in the United States today, at least to an acceptable degree.

(2) For technology to be efficiently transferred, there must exist recognizable specific social needs to which it can be applied. Certainly, the list of social needs frequently cited—higher rate of economic growth, pollution abatement, improved mass transportation, better health care, more effective crime prevention, more systematic and sanitary means of wastes disposal, improved education and training methods—are recognizable to the majority of U.S. city dwellers and a great many rural residents as well.

(3) The process by which technology can be transferred from its point of origin to utility in another context is extremely complex. Too little is known about the total process; no readily accessible body of knowledge exists. But empirical knowledge is being generated by existing experimental programs.

(4) An awesome list of barriers to acceptance of innovation has been compiled by those who have practiced transfer or studied the transfer process. Some of the barriers will likely always exist and need only be recognized in the design of transfer programs. Others, once recognized, can be prevented by designing transfer methods that avoid them. Still others can only be changed by evolution of the environment. And some perhaps appear as barriers only because we know too little

about creativity, innovation, human behavior, group dynamics, and the processes by which ideas become accepted within organizations.

What Is Government's Role?

If we accept that it is in the national interest to attempt to channel new technologies in promising directions, we must ask who will perform the channeling function.

No firm recommendations will be made here on the extent to which this function should be conducted in the public sector. But the authors will raise some of the questions, attempt to define some of the issues, and report on the degree of Government involvement in some past and present programs of this type.

A central issue is the degree to which the Federal Government should accept responsibilities for direct action programs to stimulate economic growth.

Another issue is the degree to which the Government should accept responsibility for the active development of national resources. Logical arguments can be made that technological knowledge has become as important to regional and national economic health and growth as were natural resources in the past. Those favoring substantial Government involvement in programs to transfer technology argue that the precedent for such Federal involvement is in past and present Government programs to make rivers navigable, to aid in the exploration, use, and conservation of the Nation's mineral supplies, and other such programs.

A third question concerns regional balances. Arguments have been made in favor of Government support of technology transfer programs on the basis that such programs will tend to offset regional imbalances in technological sophistication resulting from the concentration of Federal R. & D. funding in a relatively few States.

A fourth and thorny question involves the issue of whether Government support of programs to transfer technology to the private sector would tend to work in favor of the marginal producer. The argument is that such Government involvement would interfere in the private economy because it would tend to bring to the marginal company a partial capability that must otherwise be gained through relatively high investment on the company's part.

A fifth debate centers about historical precedent for Government involvement in programs to promote scientific activity and technological achievement and to bring about the diffusion of science and technology throughout the economy. A few events of that type are mentioned here.

One of the first patent applications under the patent law of 1790 was for "a mixture which was supposed to help make salt water fresh [through a distilling process]." Thomas Jefferson, who was then Secretary of State and as such was also the administrator of the patent law, proved by experiment . . .

> That the fresh water came from the distilling process, long known and used at sea, and that the mixture added did not enhance its efficiency. Nevertheless, Jefferson suggested to Congress that instructions for building an evaporator be printed at Government expense and distributed to all shipmasters.
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> That Jefferson should propose the dissemination of the knowledge thus incidentally called to his attention suggests that the Federal Government had a duty to promote the general welfare by broadcasting this useful bit of information.[33]

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[33] Fairand, Max, "The Records of the Federal Convention of 1787" (New Haven, 1911–1937), p. 12, as taken from *American State Papers*, misc., I, 45.

That example is from among scores of Federal ventures into the application of science. Clearly the Federal Government has long been involved, and the mandate has not been based solely on military preparedness. Instead, from the beginning, there has been the implied, and often expressed, conviction that science and knowledge should be exploited by and for all mankind.

One of the more forceful arguments for Government involvement in programs to channel new technologies into civilian applications rests on the dual points that (1) the Government is the generator of the vast bulk of new science and technology; and (2) a significant potential use for the new technology is in activities generally considered to be wholly or partially in the public sphere. This case was stated as follows by the National Academy of Sciences:

> It is clear that with increased urbanization and industrialization, our country is developing a number of problems that can only be faced on a national basis—for example, education, air pollution, water resources, weather forecasting and control, pesticides, radioactive wastes, public recreation, natural resources, air traffic control, highway safety, and urban transportation. The degree of Federal responsibility in these areas will always tend to be a matter for political debate. However, there is greater consensus on the Federal Government's responsibility for seeing that the foundations of knowledge are laid in these areas than on its operational responsibility. Research related to social goals tends to be recognized as a Federal responsibility even when operation or regulation is delegated to the State or local level or left to private enterprise.[23]

Another frequently heard argument is that the Federal Government should support vigorous efforts to transfer technology because it has a responsibility to the taxpayers to ensure the optimum return on the public investment in research

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[23] *Basic Research and National Goals*, a report by the National Academy of Sciences to the Committee on Science and Astronautics, Washington, D.C., March 1965.

and development. While the goal is desirable, the logic of the argument is debatable. If the secondary beneficiaries of the new technology can make optimum use of it without artificial stimulation, then Government assistance would not seem warranted. History shows, however, that optimum use is not likely to occur naturally. And history proves quite emphatically that there will likely be a longer timelag between development of new technology and its civilian application via natural processes than would occur with some form of catalytic action.

Although the existence of some Federal responsibility in this area seems beyond doubt, there is a serious question of degree. Since two-thirds of all R. & D. work is supported by Federal funds, the Government clearly has a responsibility to make the results of this work available for the widest possible use. However, how far should the Government go, not only in making findings available, but also in selecting and tailoring reports for most effective use by private enterprise and even in promoting the receptivity of private enterprise for utilizing the advanced technology?

Science and technology can flourish only if each scientist interacts with his colleagues and his predecessors, and only if every branch of science interacts with other branches of science; in this sense science must remain unified if it is to remain effective.

Inasmuch as the Federal Government now supports three-fourths of all science and technology in the U.S., the Government bears heavy responsibility to prevent our scientific-technical structure from becoming a pile of redundancies or contradictions simply because communication between the specialized communities or between members of a single community has become too laborious.

Moreover, since good communication is a necessary tool of good management, the Federal Government, as the largest manager of research and development, has a strong stake in maintaining effective communication.

Almost everyone who has seriously studied the question agrees that the Federal Government has some responsibility in bringing about secondary applications of technology generated via public funds. The question is the degree to which the Government should go. This is one of the many areas in our economy where it is difficult to get programs underway because of the confusion between the proper roles of the public and private sectors. These difficulties seem greatest in areas where the responsibility is shared. Technology transfer is clearly one of them. And the precedents for successful sharing are few.

With the hope that existing programs might, in composite, show some pattern of legislative understanding of the degree of public responsibility in this arena, the authors spent considerable time examining the more significant ongoing programs in the various Federal agencies whose statutory responsibility embraces technology transfer efforts to any significant degree. Programs were studied in the following agencies:

Department of Agriculture.

Office of Science Information Service, National Science Foundation.

Defense Documentation Center.

Atomic Energy Commission.

National Aeronautics and Space Administration.

Clearinghouse for Scientific and Technical Information, Institute for Applied Technology, National Bureau of Standards, U.S. Department of Commerce.

National Library of Medicine.

Office of Technical Resources, National Bureau of Standards, U.S. Department of Commerce.

Science Information Exchange, Smithsonian Institution.

National Referral Center, Library of Congress.

Small Business Administration.

Government Printing Office.

The various programs currently underway within Federal agencies range, in degree of Government participation toward achievement of technology utilization, over a very broad spectrum. In fact, several orders of magnitude in terms of level of effort and level of support involved separate the programs of some agencies from those of others. And within some agencies, several different levels of effort are apparent.

Obviously, there is a need for a more clearly defined national policy in regard to technology channeling efforts. Let us pose the potential role of Government in the process in terms of eight distinct levels of effort, all representative of ongoing programs in one or more agencies at present.

Should the responsibility of the Federal Government end with:

Publication, i.e., making the results of research and development available (as in libraries, depositories, and journals) for interested parties, but placing the full burden of discovery and use on the potential user?

Bibliographic control, i.e., making it easy for the interested parties to seek out relevant publications?

Dissemination, i.e., actively delivering relevant publications to interested parties?

Communication, which implies some personal (versus only paper) involvement in defining the needs and objectives of the user and seeking to match specific technical information to those needs, so that understanding is achieved?

Education, which implies not only communicating specific information but also building the background of the recipient of the information to a level where the relevant information can be more effectively utilized?

Encouragement, i.e., actual continuing consultation with the user of the information to promote utilization (versus transfer, per se) of the technology?

Assistance, i.e., Government aid in adapting technology generated for a Government mission to make it useful for nongovernmental purposes (or one Government agency adapting its technology for the use of another Government agency)?

Development assistance, which implies Government action to add to the knowledge base and develop new technology specifically to meet needs and objectives in the civilian economy?

National policy in regard to technology utilization programs has been established in an ad hoc manner. Perhaps the time has come to reexamine all such ongoing programs to determine the value of each in relation to the accepted or recommended responsibilities of the Federal Government.

It is not recommended that any national policy limit governmental involvement to any one of the eight levels of effort outlined above. To do so would be to place undue emphasis on some sources and uses for technology and too little emphasis on others. Certainly, it would seem that the Federal Government has a legitimate role in developing weather satellites and medical research equipment (the ultimate level of Government involvement) and at the same time it has some responsibility for making available (perhaps only by storage) the results of its seemingly least useful R. & D.

What is recommended is that a national policy spell out the conditions under which Federal agencies should conduct, foster, or support programs at each of the various levels.

But before any such policy can be established, certain questions should be considered. Among these are:

- To what degree, if at all, can known innovators employed by Government agencies be diverted from their primary missions to assist in the transfer of technology—by, for example, speaking at seminars (dissemination); by conducting short courses (communication); by serving on task forces to adapt mission-generated technology to uses by other Government agencies (interagency assistance); by giving advice and counsel to scientists and engineers in private companies and other governmental bodies who have a demonstrated capability to utilize it (encouragement); by sabbatical leave to champion an area of technology; by personal in-house development of innovations not oriented to the mission of the employer agency (development assistance)?
- To what degree should control of technology transfer efforts be centralized? This question apparently cannot be answered on the basis of available information and should be the subject of detailed and careful study.
- How can technology relevant to the problems and objectives of external groups be identified by the originating agency? This function is, of course, mandatory for the success of a technology transfer program. One approach used by NASA—stationing "technology utilization officers" at facilities responsible for the generation of

technology—has been effective. Should other agencies be encouraged to select capable personnel to perform a similar role?

- Much of the science and technology generated by Government is of a very complex and sophisticated nature. In its primary form—the technical report—it frequently is readily understandable only by scientists working in the same specialty. But external utility might be in industries or disciplines much different from that of the researcher who generated the technical report. Should Government serve an interpretive function in such cases?
- Efforts to effect the utilization of new technology for economic advancement would be greatly enhanced by a better understanding of the processes and varying modes by which new ideas become accepted and innovations adapted in various organizations expected to use the results of Government research and development. Sufficient fragmentary evidence exists to permit the formulation of several hypotheses. Detailed analysis should be made of the innovative process and searching study of the environmental factors that contribute to entrepreneurship. The results would be extremely useful in developing the most effective means of channeling new technologies in promising directions.
- Smaller businesses, which generally have limited scientific and technical resources, pose a special problem for those concerned with the nongovernmental utilization of Government-sponsored research results. NASA, for example, has designed its technology utilization program in such a way that much of the dissemination activity will eventually be self-supporting (i.e., paid for by the beneficiary rather than the originator of the technology). But smaller businesses have difficulty

justifying expenditures for this purpose—even though the cost is relatively low. (The larger organization generally not only has better inhouse capability to interpret and understand the implications of new scientific information but also has a broader technology consumption pattern, i.e., its technical interests are less specialized, generally, than those of the small company.) Effective, low-cost means of serving the needs of smaller businesses—without subsidizing them in opposition to the principle of open market competition vis-a-vis the large companies they compete with—should be explored. Currently, NASA and AEC have underway joint experimental programs with the Small Business Administration. These programs may provide some understanding of how to cope with the seemingly special needs of smaller business.

- In effecting technology utilization it is important to have a thorough definition of what technology is available for use. This demands efforts to pinpoint innovations and new knowledge, to describe such innovations and knowledge in terms understandable to potential users in many industries and disciplines, and to arrange all such knowledge in a system that permits the potential user to find what he wants without having to sort through a lot that he does not want. (Because of sheer volume, this argues for computerized systems and for switching devices among various systems.) This is necessary for even the lowest levels—publication and bibliographic control—of Government involvement in true technology transfer (as differentiated from mere publication).

- The most effective forms of technology utilization demand a personal champion of the technology. This argues for wider use of a type of specialized information center not commonly found, i.e., a center staffed by articulate, knowledgeable, adaptive, extrapolative "missionaries" who can communicate an understanding of new technology and encourage its use. While the cost of such efforts should be borne in large part by the users, the initial investment is heavy. Should the Government help with "startup" costs?

- Most potential users of Government-generated technology seem unaware of the channels through which such technology can be made to flow to them regularly. There appears to be a need for local or regional "referral centers," to which any qualified seeker of knowledge can turn for guidance in obtaining that knowledge. Such centers might function as pipelines to smooth and expedite the flow of new technology into promising potential applications.

No readymade answers of substance exist for any of those complex questions. All demand careful study which should probably involve the technology's originators (for example, DOD, AEC, NASA, NSF, and NIH), its potential users (private industry, Federal, State, and local government, and universities), those with experience in transferring technology (for example, research institutes, universities, and publishers), and those who must, in the end, determine policy (legislators).

When a national policy has been decided upon, the question may still remain as to where ideally to house the function or functions within the Federal Government.

It is highly likely that a single agency to perform the function would not be the best solution. Too many different levels of activity and kinds of mechanisms will be required for effectiveness to permit such an easy answer. Centralizing the responsibility would also probably place the obligated agency in a most uncomfortable position vis-a-vis other Federal agencies. To transfer technology, one must have some technology to transfer. For one agency to police the activities of others to the degree necessary to ensure the reporting of new technology would seem to place the entire program in jeopardy. (Discussions relevant to this issue have occurred in relation to the establishment of a National Research Data Processing and Information Retrieval Center[34] and to the oft-proposed establishment of a department of science.)[35]

While it might readily be feasible to assign some abstracting, indexing, publishing, referral, and document dissemination functions to a central agency, intensive efforts that demand inhouse adaptation and development as well as thorough understanding of the technologies involved are probably best left to the agencies originating the technology.

Between those two extremes (represented on the one hand by the Clearinghouse for Scientific and Technical Information and on the other by the Atomic Energy Commission's fostering of civilian nuclear energy generating capability) lies much ground for debate. It is possible that social inventions of a high order will be needed to meet the requirements of effectiveness and efficiency. Certainly, such recently established efforts as the AEC's Office of Industrial Cooperation, NASA's Office of Technology Utilization, and the Commerce Department's State Technical Services Pro-

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[34] Hearings before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center of the Committee on Education and Labor. U.S. House of Representatives, May, July, and September, 1963.

[35] This proposal has been debated at various times for 85 years. In the 1880's, it was proposed and the issue resolved by the Allison Commission, a Joint Congressional Commission, which concluded that the Government's scientific establishment and the scientific community in the universities had already grown too complex for such a change in organizational structure.

gram will provide valuable empirical evidence some years hence of the relative effectiveness of various experimental approaches. Meanwhile, interagency cooperation and exchange of knowledge gained should be encouraged, and organizations such as COSATI might be assigned some responsibility for collecting and synthesizing the knowledge gained through these programs.

Some Existing Programs

This section reports on some existing Federal programs to channel technology or technical information or documents from originator to potential user.

While no existing program shows promise of becoming a full answer to the need for a mechanism to channel new technologies in promising directions, several programs are providing valuable experience in the design of better systems. Some of them can likely become components of a national system that might be designed at a future date.

Following are reports on some of these programs:

Science Information Exchange. A component of the Smithsonian Institution, SIE is funded principally by the National Science Foundation. It is primarily an inventory of current and ongoing research tasks. It can therefore tell a practicing scientist or engineer who is working in his field and supply a brief sketch of what these investigators are doing.

SIE's main method of operation is to obtain copies of detailed proposals or work statements for R. & D. from various Federal agencies, write descriptions of tasks expected to be performed, and categorize the tasks in terms of the various disciplines and topics to which the research might be relevant.

SIE was established to serve R. & D. program managers in Federal agencies, helping them to avoid duplication, establish priorities, maintain balances among related research fields, locate special research capabilities, and perform other useful tasks.

The existence of the information, however, allows SIE to perform a kind of technology transfer function in that SIE will tell any qualified scientist or engineer who is working in specific fields of interest. SIE thus serves a referral or clearinghouse function—or acts as a coupling mechanism among technical men with similar interests in different disciplines, industries, sectors, and regions.

SIE got its start in 1949, when rapidly expanding Government programs in medical research caused several agencies (NIH, ONR, and others) to establish voluntarily, via interagency agreement, a Medical Sciences Information Exchange. In 1953, the mission was broadened to become the Bio-Sciences Information Exchange, and the Smithsonian Institution was asked to run the program. In 1960, the mandate was enlarged to include the physical sciences and the organization was renamed the Science Information Exchange.

Since 1949, the Division of Life Sciences has accumulated approximately 300,000 records of research grants, contracts, projects, and tasks. In 1962, the Division of Physical Sciences was organized and began the collection of information on current basic and applied research in chemistry, physics, mathematics, earth sciences, materials, electronics, and engineering sciences.

SIE differs significantly from library, documentation center, and technical reference service operations in a number of respects. SIE is concerned only with records of research, planned or in progress. It does not receive progress reports, abstracts, or other forms of *published* research results. All information is supplied to SIE on a voluntary basis.

Information about each research task is registered on a single-page Notice of Research Report by SIE professional analysts with the following information:

(1) The name of the supporting agency, supporting bureau or office, and, if it is multiply funded, the cosponsors; (2) a specific title for the project; (3) the names, departments, official titles, and locations of professional people engaged on the project; (4) the name and address of the institution conducting the research; (5) a 200-word summary of the proposed or undertaken work; (6) the specific location where the work is being done; (7) the startup date for the research and planned conclusion date; and (8) the annual level of effort in dollars.

The 200-word summary of the research is indexed with 1 to 45 descriptive words for each project.

In the life sciences, Dr. Monroe Freeman of SIE estimates that 90 to 95 percent of all the research underway—45,000 to 50,000 tasks annually—that is of a federally funded nature is brought into the SIE information stream. Comprehensive coverage of the physical sciences has not yet been achieved.

In addition to its referral function, SIE provides other kinds of services. These are:

1. *Preparation of catalogs.* There are two types of catalogs: the first is a listing of all projects supported by a single agency with the projects indexed according to a predefined method estab-

lished by the sponsoring agency. In the second type SIE has the job of collection and the major intellectual task of organization and editing. These catalogs are multiagency and multidisciplinary. A good example is the water resources catalog prepared at the request of the Department of the Interior and now being sold by the Government Printing Office. Catalogs are prepared by SIE for Government agencies only. However, at the option of the requesting agency, they may be provided to the public through the Government Printing Office or in some other fashion.

2. *Compilations.* These are computer printouts of work in a given field. For example, a job currently in progress involves preparing a compilation to show all work underway relating to the mobilization of urban resources.

3. *Specific topical searches.* Where a scientist or engineer wants to learn who is working in his specific field, SIE will provide a summary sheet for each ongoing project in that field.

4. *Name searches.* This is provided to program managers and project officers in Federal agencies to help them select grantees and contractors and allocate research priorities. For example, a program manager or an awards committee in a Federal agency may have 150 applications for grants whose names they send to SIE. SIE will conduct a computer search of all its information and tell how many ongoing research projects each grant applicant has, in what agencies, at what level of funding, how far toward completion they are, and other salient information.

During 1964, SIE answered 5,000 questions of the type 3 kind, and during the last 12 months, it supplied about 1 million full-text copies of summary sheets of ongoing work.

Atomic Energy Commission. Since its inception in 1946, the AEC has had a vigorous program for the dissemination of unclassified scientific and technical information to encourage industrial usage. The Commission has provided consulting services, training, and other assistance to the nuclear industry.

Recently, AEC decided to extend the boundaries of its industrial cooperation program to encourage consultation with respect to nonnuclear applications of its nuclear-oriented work and to allow the use of its facilities, equipment, and services in the performance of limited research and development work toward nonnuclear industrial applications.

For that purpose, AEC has established Offices of Industrial Cooperation to serve as a bridge between the laboratory and industry. The Offices are charged with carrying out the following functions:

(1) To actively search for items of information and disseminate this information to industrial organizations; (2) to be aware of the needs of particular sections of industry; (3) to encourage the industrial participation program; (4) to arrange industrial consultation and visits by industry representatives; (5) to work with such local organizations as now exist which will be suitable for its general purposes.

The major difference in the AEC's technology utilization activities since the establishment of Offices of Industrial Cooperation is that the laboratories where these offices exist can now make overt gestures toward industry to enhance the transfer of nonnuclear technology resulting from nuclear R. & D.

The following statement comes from the first semiannual report of the Argonne Office of Industrial Cooperation, January 1 to June 30, 1965:

> An observation which occurred quite early was that the size range of the transfer items in the companies to which technology can be transferred is very great. For example, a transfer item can be anything from an experimental boiling reactor to a thickness gauge; or anything from a voting machine to a Holmium Heat Sink. It can be a finished product ready for production or an idea. An entire new company can be created and therefore be a transfer item as is the man who takes a skill to the company. The industries involved in this business of technology transfer may range in size from General Electric or du Pont—companies with sophisticated research capabilities and interests—to a two- or three-man production shop with no research capability or interest. This means that the system which is set up to transfer technology from Government research to industry must be flexible and versatile enough to cover these wide ranges.
>
> It is also observed that there are two essential components of technology transfer. These are an automated information retrieval and dissemination system and a personal contact. The information pile-up has become so great that information is essentially lost unless a selective dissemination system is perfected. In addition to the identification and location of information, there must be a personal contact between the source of information and the industrial user. This personal contact serves several functions. He can help locate information, aid in adapting it for use, and probably more important, convince the industrial user that the available information could possibly be of use to him.

In the Atomic Energy Act of 1954, the Congress established policies that bear upon making available to industries, for nonnuclear uses, the results of the AEC's research, development, and industrial operations. Section I of the act declares it to be the policy of the United States that:

> The development, the use, and control of Atomic Energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise. . . . The dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding to enlarge the fund of technical information.

In keeping with that national policy, the AEC strongly supports the objective of assuring the maximum availability of results of Government-generated research for beneficial use of the civilian economy. Reports Dr. S. G. English, assistant general manager for research and development, AEC:

> Our national laboratories and other principal contractors have been encouraged to take all reasonable steps to promote the transfer of the results of AEC technological developments to the civilian sector. In 1964, a copy of the implementation of this policy was extended beyond application for nuclear-oriented purposes into the area of potential use for nonnuclear purposes. This underscores our recognition that our ideas, inventions, developments, processes, techniques, materials, equipment, instruments, etc., which resulted in AEC research and development should be available for use throughout the national economy.

The AEC has been using 13 different means of transferring the results of its R. & D. efforts. These areas were recently reported upon in an AEC study of its technology transfer activities, and excerpts follow:

DTI Services. AEC's Division of Technical Information is the only AEC information program which has a specific "line-item" budget appropriation. Its most important services are:

> Publication of five quarterly Technical Progress Reviews dealing with civilian power reactor and isotope technology.
>
> Publication of the semimonthly *Nuclear Science Abstracts*, which is the world's most comprehensive abstracting and indexing service devoted to nuclear science and engineering.
>
> Publication of 12 to 15 books and monographs per year.
>
> Management of the Engineering Materials Program, which makes available drawings, specifications, and design criteria.

Management of AEC's publication distribution network.

Coordination with other Government agencies, including the Clearinghouse for Federal Scientific and Technical Information.

Topical Reports. AEC encourages contractors to publish topical reports, which are often annual reviews of the status of programs at the various sites.

Technical Journals and Meeting Papers. Almost all of AEC's contracts provide specific encouragement for scientists and engineers to publish unclassified findings in the open literature.

Trade Journals. Probably the most widely read items of technology are those which appear in trade journals. This is an attractive mechanism, for more than others it tends to get the right kinds of information to the right people. AEC-funded technology naturally appears in journals specializing in nuclear development. Only occasionally does it appear in others, such as those in the metalworking field or those more business oriented.

Seminars and Information Meetings. Almost all AEC facilities conduct regular seminars and information meetings. However, only a limited number of such meetings have been held for the express purpose of transferring AEC-sponsored technology to industry.

Advisory Boards. There are currently 21 committees and boards which provide advice and guidance to AEC. Most of these advisory committees are concerned with specific programs or problems, such as Nuclear Cross Sections Advisory Group, Computer Advisory Group, Reactor Physics, Biology and Medicine, etc. The members of the committees are leaders in their respective fields, and as such provide a subtle mechanism for the transfer of information.

Information Centers. At the present time there are 12 specialized information centers located throughout the AEC contractor complex. Each operates in a very specific, very narrow range and is designed to be the most complete repository of information in its field.

Consultation Services. AEC policy provides for several types of consulting services to industry on a nondiscriminatory basis. One type, offered without charge and more properly identified as a conferring service, is short term; for example, the need for clarifying information on requests for bids, or an inquiry relating to a published article. When formal consultation is required, such as involving the solution of a specific technical problem, a somewhat more regulated approach is used and costs are recovered by a system of fees established by AEC.

Work for Private Industry. To meet its own program needs, AEC has established certain unique facilities. AEC's policy as expressed in Immediate Action Directive No. 7600–2, September 14, 1964, encourages the use of these unique capabilities by private industry insofar as: (1) It would not adversely affect AEC's programmatic work; (2) it would be conducted on a nondiscriminatory basis; (3) it would be provided on a full cost recovery basis wherever practicable; (4) it would act to provide "effective" technology transfer; (5) it would apply only with respect to AEC's unique or special capability.

Access Permit Program. Since 1954 the AEC, under its Access Permit Program, has made available classified information to individuals and companies engaged in the civilian use of atomic energy. This is accomplished through plant tours, briefings, and the furnishing of reports and drawings. At the present time there are about 550 Access Permits in effect; in almost every case the permit holder must bear the cost of obtaining security clearances.

Vendor Subcontracts. The vendor-buyer relationship is an excellent means of technology transfer. To begin with, the circulation of requests for bids informs manufacturers of changing requirements. Although the direct know-how is transferred to the successful bidder, there is usually an appreciable gain in the state of the art for the entire industry.

News Releases. News releases by AEC and its contractors are an important method of information dissemination. While they do not contain detailed technology, they are useful to highlight the existence of new developments and provide references for further contact.

Patent Policy. The AEC's patent policy is to ensure that atomic energy technology developed with public funds is made available freely to all U.S. citizens.

NASA Office of Technology Utilization. The Space Act of 1958 charged NASA with the obligation to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

In response, NASA has evolved a program under an assistant administrator for technology utilization to identify new technology resulting from the agency's broad ranging R. & D. programs, to report it, where practical, in industrial terminology, and to communicate it to civilian organizations through several mechanisms, including regional dissemination centers.

The NASA Technology Utilization Program draws upon a resource provided by the Scientific and Technical Information Division, which collects (on a worldwide basis), abstracts and indexes, and brings under bibliographic control published and unpublished literature relating to aerospace activities. Thus, the information bank available for the NASA technology utilization effort is broader than the results of NASA research and development alone.

The NASA technical information collection now totals about 200,000 documents and is increasing at the rate of about 5,000 items per month.

At the same time that incoming reports are being processed for announcement, a copy of each report is microfilmed (on microfiche) by the NASA Scientific and Technical Information Division (STID). Thus the contents of 1,000 average-size reports could be fitted into a shoebox.

The reports are indexed in great depth on magnetic tape to permit literature searching by computer. The tapes are updated twice monthly, permitting retrospective searching from a variety of viewpoints. This also forms the basis of the NASA Selective Dissemination of Information Program (SDI), a computer-based system for notifying individual scientists and engineers of new reports and journal articles of value in their particular work. SDI can be likened to a library run in reverse, where people (i.e., their specifically defined interests) are catalogued as well as acquisitions. As new reports are received, they are matched against the interests of individual users.

NASA is currently beginning an experimental program to examine the feasibility of giving scientists and engineers remote access to the computerized information bank to permit them to "browse" and search as they desire on a time-sharing basis via remote consoles connected to the central computer.

The major program elements of the NASA Technology Utilization Division are: (a) Identification of industrially relevant new technology; (b) evaluation of that technology to determine its significance and import; (c) publication of especially useful new information in industrially oriented language and format; and (d) dissemination of the information via traditional means and via regionally deployed contracting organizations (universities and research institutes) which match the new technology to the needs, interests, and objectives of organization in their regions.

The identification function is performed at NASA field centers primarily by technology utilization officers who monitor NASA research and development work at the centers and in contractor organizations to identify useful new technology. Important new technology is reported in the form of a "flash sheet" and described in considerable detail with potential nonspace applications suggested. The flash sheets are then sent to research institutes under contract to NASA where the reported innovations are evaluated to determine their significance, novelty, and industrial relevance. Innovations that pass this screening are published in one of two formats: (a) As Tech Briefs, one- or two-page bulletins; or (b) as Technology Utilization Reports, lengthier documents covering in detail innovations deemed especially significant and useful for secondary purposes. (Approximately 150 industrial inquiries are generated, on the average, by each Tech Brief.)

In addition, the NASA Technology Utilization Division publishes new technology information in (a) Technology Utilization Notes—collections of groups of innovations in a given field, such as *Selected Welding Tips;* (b) Technology Surveys—state-of-the-art reports on aerospace contributions to entire areas of technology, where the space program has brought about a significant increase in the available knowledge in a given area. Surveys published thus far include *Advanced Valve Technology*, *Inorganic Coatings*, *Plasma Jet Technology*, *Microelectronics in Space Research*, *Magnetic Tape Recording*, and *Hazardous Materials Handling* (surveys are prepared under contract by authorities in the fields to be covered) ; and (c) special publications—handbooks, conference proceedings, special studies, and selected bibliographies.

NASA's eight experimental regional dissemination centers are special coupling mechanisms at the local level. The centers are: (1) Midwest Research Institute, (2) Indiana University, (3) Wayne State University, (4) University of Maryland, (5) University of Pittsburgh, (6) North Carolina Science and Technology Research Center, (7) Southeastern (Oklahoma) State College, and (8) University of New Mexico.

Each center offers a variety of services to private companies or other organizations in their regions: Among the services are:

Application Engineering. Professional personnel in the regional dissemination centers (RDC's) help company technical people define their problems and objectives.

Retrospective Searching. Each RDC either has a computer or obtains computer service from another RDC. A corporate engineer can pose his question to the RDC, whose personnel will devise a search strategy and conduct a retrospective literature search via computer to seek relevant information.

Selective Dissemination. Each RDC builds an interest profile for its "customers." This is a description of each person's (or organization's) continuing interest in language compatible with the NASA Technical Information System. As each new computer tape with references to the latest NASA technical information is made available to the RDC, interest profiles can be matched against the descriptors on the tape and a set of references with abstracts will be called out by the computer for each person being served. Thus technical people can be continuously updated.

Other Services. RDC's also bring about the coupling of new technology and potential new application by conducting occasional conferences and seminars, which bring companies into contact with leading scientists and engineers in NASA centers, NASA contractor organizations, and elsewhere. The RDC's also perform a referral function, leading customer companies to sources of additional information and to individuals in NASA who can provide them with needed information in depth.

The dissemination portion of the NASA Technology Utilization Program is designed to be eventually self-sustaining via users' payment of fees for services rendered. Membership fees are based on company size, volume of service rendered, and other factors, and range from less than $500 to more than $15,000 per year. More than 130 companies are now paying annual membership fees at three centers. At other centers more than 100 additional companies have paid for seminar attendance, individual literature searches, and the like. More than 3,000 companies are receiving some measure of service from the centers.

Table 2 gives some other measures of the NASA Technology Utilization Program:

TABLE 2. SOME MEASURES OF EFFECTIVENESS OF NASA PROGRAM

Services	Fiscal year 1963	Fiscal year 1964	Fiscal year 1965	Fiscal year 1966
Tech Briefs published	0	123	300	[1] 600
T.U. special publications published	0	9	11	[2] 40
Active RDC's	3	7	8	10

[1] Projected on basis of first quarter, fiscal year 1966, processing and expected input from expanded contractor reporting.
[2] Projected on basis of first quarter, fiscal year 1966, production of publications and work in process.

Clearinghouse for Federal Scientific and Technical Information. Located within the National Bureau of Standards in the Department of Commerce, the clearinghouse is primarily a document sales agency, but also performs other information dissemination functions.

It was established in answer to a recommendation in 1964 by the Federal Council for Science and Technology that the Department of Commerce expand its clearinghouse functions, building upon the Office of Technical Services, then in existence.

The clearinghouse makes available, at low cost, copies of unclassified and unlimited R. & D. documents resulting from the work of many Government agencies. Its principal services are:

(1) Sale of reports (more than 50,000 a year) based on Government-sponsored R. & D. and sale of translations of foreign scientific and technical literature.

The availability of new documents is announced in several ways: (a) Via mention and abstracting in *Fast Announcements*, a new release sheet indicating the availability of significant new documents and grouped by subject fields; and (b) via announcement in one of the accepted announcement journals, including *U.S. Government Research Reports*, which list documents generated by agencies other than NASA and AEC; *Nuclear Science Abstracts*, which lists nuclear science documents and publications; *Scientific and Technical Aerospace Reports* (STAR), which lists new reports of the aerospace community; and *Technical Translations*, which lists new translations of important publications originally issued in foreign languages. Recently, the clearinghouse has begun issuing a *Government-Wide Index*, a monthly consolidated index to Government-sponsored R. & D. documented results.

(2) Literature searching services, which have recently been broadened. Clearinghouse collections searched include unclassified and unlimited research reports on defense, atomic energy, space, and other agency projects, as well as technical translations and information on Government-owned patents. The service is operated by the clearinghouse in cooperation with the Department of Agriculture, the Department of Interior, and the Science and Technology Division of the Library of Congress. The clearinghouse reports that steps are being taken to make available the literature resources and specialized information services of other Government agencies as well.

(3) A referral function is also performed by the clearinghouse, which is setting up a master file of information sources in the physical sciences and engineering that include Government-sponsored centers and private industry. The clearinghouse cooperates with the National Referral Center of the Library of Congress in providing the service.

(4) Selective bibliographies are also compiled in many areas of broad interest, such as plastics, welding, transistors, lasers, etc. A free list of these bibliographies can be obtained by writing to the Clearinghouse for Federal Scientific and Technical Information.

(5) Technical information contained in selected Government research reports is examined, reviewed, and "packaged" for industry's use and distributed to such local groups as universities, technical assistance organizations, State and regional economic agencies, professional technical consultants, and others. The packages consist of selected abstracts, indexes, literature reviews, and other information aimed at specific industrial needs, e.g., metal working, textiles, chemical processing.

The clearinghouse now has 4,000 subscribers to its biblographies, with about 80 percent from large companies. Often, one company represents a dozen or more subscribers, and for example, one large Midwestern firm has 119 people subscribing to the bibliographies.

Fast Announcements are presently mailed to 20,000 people. Local groups—State chambers of commerce, manufacturers' associations, consulting engineering groups, and others—cosponsored initial meetings with field offices of the Department of Commerce to explain the program and encourage industry use of it.

State Technical Services Program (*Department of Commerce*). The newest Federal service in technology transfer is based on legislative authority only 6 months old, and, of course, will likely not reach operational status for some time. This is the State Technical Services Program, to develop institutions in the States to disseminate technical information and otherwise assist local business and industry to obtain and make use of scientific and technical information emanating from federally funded research and development.

The purpose of the program is broadly stated in the enabling legislation as providing "a national program of incentives and support for the several States individually and in cooperation with each other in their establishing and maintaining State and interstate technical service programs designed to achieve the ends" of wider diffusion and more effective application of science and technology in business, commerce, and industry.

The technical services to be provided by the State institutions under the program are classified as (1) preparing and disseminating technical reports, abstracts, computer tapes, microfilm, reviews, and similar scientific or engineering information, including the establishment of State or interstate technical information centers for this purpose; (2) providing a reference service to identify sources of engineering and other scientific expertise; and (3) sponsoring industrial workshops, seminars, training programs, extension courses, demonstrations, and field visits designed to encourage the more effective application of scientific and engineering information.

The initial step under the program is the preparation of a plan and development of a means of implementing it. Specifically, the legislation states:

> The designated agency [organization within each State appointed to administer the program by the governor] shall prepare and submit to the Secretary [of Commerce] in accordance with such regulations as he may publish: (a) A 5-year plan which may be revised annually and which shall: (1) outline the technological and economic conditions of the State, taking into account its region, business, commerce, and its industrial potential and identify the major regional and industrial problems; (2) identify the general approaches and methods to be used in the solution of these problems and outline the means for measuring the impact of such assistance on the State or regional economy; and (3) explain the methods to

be used in administering and coordinating the technical services program. (b) An annual technical services program which shall (1) identify specific methods, which may include contracts, for accomplishing particular goals and outline the likely impact of these methods in terms of the 5-year plan; (2) contain a detailed budget, together with procedures for adequate fiscal control, fund accounting, and auditing, to assure proper disbursement for funds paid to the State under this act; and (3) indicate the specific responsibilities assigned to each participating institution in the State.

This program, then, is designed to provide local access to unclassified and unlimited information generated by Federal R. & D. It will not permit special tailoring of the information to the specific needs of the individual user, however, because the law states that no services may be specifically related to a particular company, public work, or other capital project except insofar as the services are of general concern to the industry and commerce of the community, State, or region.

Some Proposed Mechanisms

The application of technology to needs and objectives in the civilian economy can result in important economic, social, and cultural benefits. A huge and rapidly growing inventory of scientific knowledge and technological capability exists in the United States as a result of continuing high public investment in research, development, and engineering. Reliance upon traditional processes for the diffusion of science and technology results in undesirable lags in the application of that knowlege and capability in contexts outside the military/space realm.

It is possible to catalyze the transfer process. Existing experimental programs have been successful in bringing about some transfer and have provided an opportunity for learning. But we still have much more to learn if we are to effectively create a catalytic effect.

Our ability to bring about technical innovation appears to have outrun our capability for social invention, at least momentarily. "It is a fair comment that industrial societies have shown little originality or ingenuity in creating institutions to ensure that all new ideas will be swept into the net and that nothing will be lost." [36]

In recent years, when at last noteworthy scholarly attention has been paid to the question of technology transfer, it has become increasingly apparent that new mechanisms must be devised to perform the transfer or channeling function.

It is now recognized that:

> In a society as complex as ours, it would be sheer coincidence if the producer of new knowledge or ability should meet with the potential user.
>
> We need intermediaries, variously described as innovators, merchandizers, advocates, couplers, entrepreneurs. No matter what they are called, it is they who must match the potential of scientific knowledge gained through research, the production capability resulting from engineering development of research results, the physical needs and wants of society as interpreted by marketing research and analysis, and the cultural values of this society as reflected by economic, social, and political attitudes and activities. Without them, there will be haphazard match at best between the means and ends.[37]

What is being demanded are mechanisms that will take the technology to the potential user rather than to hope that the potential user might seek out or stumble across the technology. That implies making available relevant and accurate information to the potential user in a language and form that he understands, at the time when it is useful to him, in an environment conducive to his acceptance of it.

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[36] *The Sources of Invention, op. cit.*, p. 9.
[37] Schrier, *op. cit.*

A competitive free enterprise system works in favor of the application of new technology. The pressures of the marketplace spur the innovative process. As one spokesman noted: "In today's economy, if you can't say your product is 'new and improved,' you had better be ready to say '20 percent off.'"[38] But motivation and desire are not sufficient conditions for solution of the problem. The desire to keep from drowning does not always teach a man to swim.

In an earlier time, when the technology was less complex and less voluminous, the technically trained entrepreneur was able to seek out the information he needed. That capability diminishes each day.

The pace of technological change, the volume of new technology being generated, the multidisciplinary impact of technology, and the multiplicity of diverse uses for new knowledge, create a need for social invention. Doing less leaves us in a defensive rather than an offensive posture in relation to change.

The unmet human and community needs with which we are most concerned today have one common element: Their solution, in a technological sense, will be largely dependent on the ability of private companies to muster all of the required technology and apply it in a highly specific fashion.

No one doubts the ability of existing corporations to design systems to solve many of the problems. But these will not be the optimum systems unless all the reasonable alternatives can be examined.

The development of a desirable mass transit system depends, in the end, on an ability to make the best bearings and seals, the best low-cost auto-

[38] Gadberry, *op. cit.*

matic control systems, the most efficient air-conditioning equipment, the most effective sound and vibration damping, and other related hardware items.

Thus, the channeling of new technologies to technical people in private companies must be the central objective of any effective technology transfer program. As Sumner Myers noted:

> An invention might be conceived in or out of a business firm. It may be perfected in or out of a business firm. But, sooner or later, if it is to be introduced into the economy, this will be done through a business firm.[39]

Perhaps social invention is required on two planes: One, to get new technology to those private companies who can apply it, both as a means of speeding economic growth and as an essential element in the solution of public problems, via a system responsive to the needs of individuals in the technical community; and two, to aid, from a systems viewpoint, in creating the means or an effective market for applying new solutions to our problems.

For example, the many technological inputs useful in the design of better air-pollution control devices need to be channeled to private companies serving that market. Secondly, a means must be devised to bring together all the fragmentary influences which will determine whether new control methods are indeed put to use.

To solve effectively, for example, the air pollution problem in any metropolitan area demands the cooperation of the many municipalities, counties, and other political subdivisions that make up that metropolitan area. In some cases (the New York, Kansas City, and Cincinnati areas, for example), more than one State is involved. Solving

[39] Myers, Sumner, "Attitude and Innovation," *International Science and Technology*, October 1965.

the water pollution problem in Lake Erie and making maximum use of that natural resource must involve two countries, eight States, and uncounted local governmental bodies.

The greatest motivation for the use of new technology is the existence of a market to which it can be applied. But how can private industry be expected to make huge investments in the engineering effort required to convert new technological knowledge into practical hardware when there is not the least assurance that the resulting devices can be sold at a profit? Thus, an apparent need arises for social innovation at the market level.

Some entrepreneurial efforts of this type have been accomplished. One good example is the School Construction Systems Development Project in California, where advanced building design concepts are being applied because several school districts indicated a willingness to buy the resulting product. The entrepreneurs involved created a market of sufficient size to justify the investment by several private companies in the engineering of advanced building components and subsystems.

It must be remembered that technology does not occur in readily usable packages. To solve a specific problem in one context may demand the pulling together of technology developed for a dozen other purposes, its adaptation to the specific situation (at considerable cost), plus, often, the invention of additional technology. Making effective use of new technology often requires more investment and more creative ability than did the creation of that technology in the first place. The competitive market is an exceptionally fine mechanism for bringing about that investment and application of ingenuity. But the marketplace has not been able to function effectively in relation to the pressing urban problems of today. The influences that would create a market are so fragmented that no market has been shaped or defined.

Where a problem exists, there generally is economic opportunity. Where there is economic opportunity, private business should be capable of response. But in the case of most urban problems, there is a missing link—a definable, responsible consumer.

Perhaps a related reason why these problems have not been solved is that a highly sophisticated systems approach must be employed for factors to be considered are many and in dynamic relationship. The systems capability required exists in few places outside the space/military sphere.

That kind of reasoning stands behind the experimental programs underway in California where large private companies—accustomed to working on space/military problems—have been asked to consider questions like the control of crime and delinquency.

When the State of California decided to sponsor four studies of such earthly problems, more than 50 companies, mostly from aerospace, competed for the four $100,000 contracts. That each winning company has reportedly spent more than twice that amount in consideration of the problem indicates the responsiveness of private industry to the existence of a market.

Our problem, it seems, is that we have not been able to convert our unmet human and community needs into definable markets that would be recognized economic opportunities. Senator Gaylord Nelson has recently proposed studies similar to those in California on a national scale. In introducing the proposed legislation (S. 2662), the Senator noted, in part:

> It would be highly in the national interest to begin devoting a portion of the talents and brains of *our*

defense and space industries to other national goals of a great society. This would require no diminution in either our defense or space commitments. We can do both—we can have guns and butter; we can have a moon shot and a national plan for the abatement of pollution; the Polaris project is not incompatible with a new and scientific attack on the terrors of crime. Moreover, the California studies have shown that private firms can help us achieve this objective. . . .

In fact this capability and brain power already available throughout the Nation is . . . a scientific weapon of demonstrated power and a source which represents a high national investment.

Our task is to recognize that we have the scientific know-how, and the men, to solve almost any problem facing society. Once we understand this, I am confident we will choose to use the resource; we will choose to set our highly trained manpower loose not only on space probes but on down-to-earth problems; we will choose to use systems analysis, the computer, and every modern resource available to us in the quest for progress.

A possible means of using those resources and at the same time bringing together the fragmentary influences for the solution of urban problems was suggested at the Engineering Foundation Research Conference on Technology and Its Social Consequences, held at Andover, N.H., July 26–30, 1965.[40]

The suggestion involves local competitions for Government grants to design systems solutions to urban problems. Patterned in part after the AEC's request for proposals on the location of its proposed new linear accelerator, the suggestion would be for the Federal Government to offer a sizable grant—or matching funds—to the winner or winners of a competition for the design of systems for mass transportation, waste disposal, and other urban problems. Proposals would be submitted by and on behalf of entire communities.

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[40] Credit for the suggestion must go primarily to Dr. Lyle C. Fitch, president, Institute for Public Administration, and Dr. Arthur Weimer of Indiana University.

The demonstration system that would likely be designed by the winning community with Federal support would be adaptable to the needs of other communities.

The value of this proposed mechanism lies largely in the ability of such a potential award to create a recognizable market—to draw together all the groups within a community who will influence the solutions to the community's problems. Thus it is felt that much will be gained even by communities that do not win awards because many diverse interests will have worked together to design proposals. Such a cooperative effort is seen as a stimulus to further cooperative efforts, and would tend to achieve a degree of cohesiveness and cooperation in many communities that did not exist before. In part, this is using the systems concept in a social and political as well as technological sense.

There is no doubt that a systems approach is required for the solution of most of the pressing problems of our urban communities, and it is frequently suggested that companies now serving the space/military market be encouraged to diversify into areas where the major problems lie. The California experiment tends to reinforce that view.

Whether such diversification would be the optimum approach to solving the problem is debatable, for the record of successful diversification by defense contractors is meager. Murray Weidenbaum has pointed out:

> Since the end of World War II many major defense contractors have sought to diversify their operations into commercial lines of business . . . . These companies attempted to utilize the technological capabilities developed in the course of their military work to design and produce a great variety of commercial items . . . . With one major exception, these diversification attempts have each been relatively small in comparison with military equipment. The exception,

of course, is transport aircraft for the commercial airlines . . . . Other than the few firms selling to the airlines, the large defense suppliers, especially in the aerospace field, have reported commercial sales of 1 or 2 percent, or even less over the years. The list of abandoned commercial ventures is a long and constantly growing one. The surviving efforts continue generally at marginal levels—either actually losing money, barely breaking even, or showing profit results considerably below military levels.[41]

Solo has also explored this question:

Differences setting the civilian apart from the space/military forms of business organizations also appear to be growing. The two sectors have taken different paths of development. It is entirely natural that this should be so, for those who produce and sell to the civilian market and those who produce weaponry control systems, instruments, and components for the military market operate in quite different environments, and are shaped by quite different forces. Sharp variances between two sectors show up—in the nature of risk, in the appropriate ethics and standards of conduct, in the means of survival and growth, in the emphasis on the costs of production in the one instance and on performance characteristics on the other, in the fabrication of the complex, perpetually changing, prototype in the one and in prerequisite long runs of standardized outputs in the other, in the buyer-seller relationships, and in the nature of organization controls.[42]

The problems of defense contractor diversification into other areas of endeavor are obviously formidable, but considering the capability that exists in such corporations, their ability to contribute to the solution of civilian problems dare not be lightly dismissed.

Another frequently proposed means of bringing the knowledge to the need—or focusing the capability on the problem—is to encourage the mobility of technically trained people. It has often been

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[41] Weidenbaum, Murray L., "The Transferability of Defense Industry Resources to Civilian Uses," Reprinted in *Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potentials*, Report on selected readings in employment and manpower prepared for the Senate Subcommittee on Employment and Manpower, Washington, D.C., 1964.

[42] Solo, "Gearing Military Research and Development to Economic Growth," *op. cit.*

suggested that sophisticated technologists and experienced systems analysis from military/space organizations be "transplanted" to organizations with marketing know-how in dealing with the civilian sector to raise their level of technical capability.

Allison has reported on that issue:

> One of the most serious phenomena we are up against is the direction in which "people transfer" goes: For it goes in the wrong direction—from civilian to defense. Donald Fink, ex-head of Philco's research activities, tells how it happens in the electronics fields: "In electronics there are two groups of engineers: Those who are still working on consumer and industrial products and those who have gone on to Government work. These two groups are quite distinct and the path from one type of occupation to the other is strictly a one-way path. They [scientists and engineers] do not go back because Government work allows them to work near the frontier of science and technology; if they are clever and hard-working, they will use the proper engineering solution, and it will be paid for." The result of this, says Fink, is that technological advance in consumer products is at a standstill compared with weapons systems. . . . We are developing scientists and enginers who do not know the free enterprise system, because they have only lived in the Federal Government environment.[43]

Most of the evidence gathered tends to support the conclusion that there is little movement of personnel between the two sectors. But whether or not such mobility can be brought about seems beside the point. It would certainly not be proper for the Government to attempt to intervene in the process by which people choose where they want to work. Nor does any other means of encouraging such mobility on a large scale seem practical.

While the lack of intersectoral mobility may be viewed as a problem per se, it represents what may be an even more difficult problem in the context of technology transfer, i.e., the difficulty in communicating from one sector to the other.

[43] Allison, *op. cit.*

A message is more likely to gain understanding and response if it fits the pattern of experiences, attitudes, values, and goals of the receiver. True communication is dependent on a number of forces, and the sender of the message can really only control a few of them. He can shape his message, and he can decide when and where to introduce it. He cannot control the environment in which the message is received and in which response takes place. the attitudes and personality state of the receiver, or the receiver's group relationships, standards, objectives, and priorities.

The problem has been eloquently described by Robert A. Solo:

> Rendering articulate the complex and the new is a most difficult task; difficult even when those who would speak together share a common language. And sharing language is far less the usual case than is ordinarily supposed. Such a language is no mere matter of grammar, syntax, and standardized vocabularly. It is also in the habits of thought, in the individual's points of reference, in his philosophy, his values, and his experience, in the form of establishing credibility, and in his manner of ordering the evidence. We speak at each other but we hardly ever converse. And if the one speaks openly and clearly of the significantly new, the other must not merely listen. He must have the capacity to comprehend and assimilate. He must be able to understand. There are two sides always, the speaking and the listening, the giving and the receiving; both require effort and skill. The communication of significantly new insights, invention, thought—even between two individuals face to face—is difficult and rare. But how infinitely more difficult when the communication of invention or discovery is not from man to man but from group to group, from company organization to company organization, from industry to industry, from sector to sector, from nation to nation, from social culture to social culture. Language, interest, outlook, distance, and time—sheath upon sheath—separate the thought and perception of one from the perception and thought of another.[44]

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[44] Solo, Robert A., "Studies in the Anatomy of Economic Progress," a working paper.

The point is: Any means of channeling new technologies in promising directions eventually boils down to communicating information on new technology from its point of origin to its point of potential use.

Rosenbloom has agreed:

> The transfer of technology—whether it be from person to person, firm to firm, industry to industry, or government to private enterprise—depends primarily on the exchange of information rather than upon the exchange of things. In the long run, therefore, the fullest utilization of the technological byproducts of military and space development will flow from a healthy and effective technical information system. This system is not a single monolithic entity, but rather is an amalgam of many loosely interlocking institutions and procedures, serving many publics, concentrating on various aims. Within it, information is exchanged not only by the storage and dissemination of documents, but also by many interactions, formal and informal, between people.[45]

Thus the mechanisms devised to perform the function will center on the gathering, evaluation, packaging, analysis, interpretation, categorizing, extrapolation, assembly, association, handling, and communication of information.

To perform those tasks well, we must learn considerably more about both man and machine. We must develop mechanical and electronic tools, primarily computer systems, to permit us to speed the routine portions of the task. And we must find, educate, and motivate people to perform the more imaginative portions of the work.

As has been reported here, some of the experience and knowledge necessary to build these man-machine systems has already been achieved and more is being accumulated from programs now underway.

An examination of history also shows that we have numerous models we might borrow from and some we might want to deliberately duplicate, ex-

[45] Rosenbloom, *op. cit.*

perimentally, to learn how to design ultimate systems.

In many instances, there is a real question whether money should be spent to search for a document, to search for knowledge and skills, or to start from scratch. Perhaps one reason that question occurs so frequently is that our models have been less than adequate, and that we have failed to combine elements of several models into one system.

There is increasingly a need to provide a means of taking the technology to the potential user, rather than hoping he will be willing and able to unearth it from its variety of resting places. The transfer of technology depends primarily on the effective communication of information, implying relevance of the information and understanding on the part of the potential user.

Meeting many unmet needs will depend, in large measure, on the ability of innovators in private companies to obtain a wide range of scientific and technical information in a form conducive to their use of it. That means that innovators in private companies must be a focal point in the design of channeling methods.

Thus we must next consider what we have learned and understand in regard to the essential elements of a system that will successfully channel new technologies from their multiple points of origin, in a variety of combinations, to their many potential points of use.

The Elements of a Transfer System

We all take the telephone for granted. When we have to wait more than a few seconds for a dial tone, we grow impatient and frustrated. When we call information—seconds seem like hours. We also take for granted the telephone directory—that innocuous book which methodically lists names and numbers in

alphabetical order. Imagine the chaos in the telephone company information centers if one day every other page in everyone's phone books were missing. Imagine your frustration if most telephone numbers were "unlisted"—if a special, prolonged, and elaborate effort was necessary each time you made a call.

Contemplate the chaos in your city if there were hundreds of different phone books—some arranged by people's national origins, others by occupations, by district or by name—yet none of them complete. Each time you needed a phone number you would have to know whether your friend was Irish, or a janitor, or whether he lived in the north side of town. Suppose that in each city the system was different—each used a different terminology or system of spelling—a janitor might be a superintendent or a maintenance engineer.

Suppose each of these phone books, large and small, is only half complete and at least a year old when it arrives. Suppose that phone books were not free but cost so much that only libraries could purchase them. Imagine your frustration if you had to go to the library each time you wanted to make a phone call.

Now what has all this to do with the so-called information crisis? The situation I have just hypothesized is a fairly accurate description of scientific communication today. There are some obvious exaggerations. On the other hand, there are even more chaotic aspects difficult to convey by simple analogy. We all use the yellow pages, the classified directory, and frequently find it difficult to locate a number because of peculiarities in our language. Gas stations are listed under service stations and sell gasoline; gas companies may be listed under power companies and sell gas. In science, terminology is constantly changing—faster than the lexicographers or dictionary publishers can cope with. Every scientific dictionary is obsolete long before it is published.

In science communication we not only call local numbers—we are constantly trying to place long-distance transoceanic calls because science is international. Our telephone operators, the information scientists and librarians, must be able to handle dozens of languages including Japanese, Russian, and other exotic tongues.

However, this is only the beginning of the difficulties. After painfully identifying the telephone number of the scientific document he needs, the scientist can't simply dial the number. He must first identify the telephone exchange that handles this number. He may be lucky and find that it is a local exchange. Quite frequently he will find that he must call a Washington exchange or some other remote city. But scientists are stubbornly persevering, and having learned the proper exchange, put through the call only to find that the line is busy. In fact, the average waiting time is a few weeks—and by then—if that hasn't discouraged him—he may find that he called the wrong exchange, the number is out of order, or disconnected, temporarily or permanently. It is not surprising that by the time his call does get through he has sometimes forgotten why he called in the first place.

The working scientist places hundreds and thousands of such calls each year. He would call more often if he did not anticipate, consciously or intuitively, delay and frustration. The net result is that he gives up and only makes a call when he is absolutely desperate.[46]

Dr. Eugene Garfield's analogy points up some of the complexities involved in the design of a national system to channel technology. William T. Knox, formerly manager of corporate planning for Esso Research and Engineering Co. and now in the Office of Science and Technology and chairman of COSATI, served as manager of Esso's Technical Information Division for 5 years. He said:

During that time I changed from a research director ignorant of the enormous problems in the technical information field and skeptical of my interest in it to one who believes that the successful solution of the technical information problem is vital to the continued health of science and technology and demands the very highest skills and capabilities of professionally trained people.[47]

A similar change of attitude on the part of many highly placed Government officials and top corporation executives will likely be required if effective technology utilization programs are to be developed.

Technology transfer—using new technology for purposes other than the specific one for which it was created—is not now given much emphasis in many Government program offices. Until it is given higher priority, major problems will exist on

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[46] Dr. Eugene Garfield, in testimony before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, *op. cit.*, p 227.

[47] *Research Management*, July 1964, p. 287.

the input side of the transfer mechanism. For locating the technology which is truly new and significant demands the cooperation of those program offices with the scientific and technical missions, and therefore the R. & D. budgets.

And on the output side of the transfer mechanism, the quality of receivership must improve. The executives and technical professionals in private companies must be exposed to the benefits they can derive from the utilization of Government-generated technology.

Between input and output must be built new bridges—not made exclusively of paper—over which the right information can be successfully conveyed. And the bridges must permit traffic in both directions.

The steps in the transfer process are:

- Finding the technical information.
- Screening out that which has current relevance for possible special emphasis—but not abandoning what remains for it may have unrecognized value.
- Organizing it in a manner that permits its rapid and efficient retrieval for a variety of potential users with different languages, interests, and orientations.
- Bringing relevant parts of it, on a selective basis, to the attention of a variety of potential users.
- Arranging for seemingly unrelated pieces originating in separated areas to be fitted together.
- Encouraging its use on the basis of its value.
- Relating it to ongoing efforts that may enhance its value.
- Organizing it so that it can not only be called out to meet specific defined needs, but also be a

source of ideas to the technical man "browzing" through it.

- Permit the full inventory to be examined in a way to allow the discovery of areas of knowledge convergency or potential breakthrough areas and areas of need.
- All this must take place in an economic and social environment conducive to change.

Let us consider the implications at each step in the process.

Finding the Information. Technology exists in many forms—in documents of many kinds, in not-yet-articulated concepts and understanding, in physical devices and systems. The documents will appear as patents, research reports, unanalyzed data, handbooks, trade press articles, papers in technical journals, proceedings of conferences and seminars, scrawlings in the notebooks of scientists and engineers, and countless other diverse forms.

The chances of finding it will not be good unless at least two conditions are met: (a) Capable people are assigned the task of seeking it out as their primary responsibility; and (b) those who generate it—the practicing innovators and their supervisors—recognize the value of transferring the results of their work and agree to cooperate.[48]

Some pioneering efforts of this type on a formal basis are underway. The Science Information Exchange, for example, has elicited the effective cooperation of most segments of the Government community sponsoring and conducting research in

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[48] The size of this task might be illustrated by the Gemini program. McDonnell Aircraft Corp., prime contractor for the capsule, has 3,196 subcontractors and uncounted suppliers to the subcontractors. Martin Co., responsible for the Titan II launch vehicle, has an estimated 1,500 to 1,800 companies supplying services, parts, and materials. The subcontractors range in size from General Electric Co. to the Blake Rivet Co., a firm with 60 employees that made the special titanium alloy fasteners used in assembling the capsule. The suppliers range in technology base and orientation from IBM to the David Clark Co., a brassiere and girdle manufacturer that made the space suits.

the life sciences which now bring to SIE's attention their current R. & D. activities. SIE has put professional analysts to work documenting those activities, for to be widely communicated, information must be articulated and recorded.

NASA is providing another model. Its technology utilization officers deployed in the various NASA installations have the primary responsibility for seeking out the important results of research and development efforts conducted in NASA centers and by NASA contractors. NASA has put teeth in its philosophy by placing contractual responsibility on its contractors to report new technology resulting from their work under NASA support.

The AEC has been successful in encouraging its scientists and engineers to recognize the importance of civilian applications of the nuclear technology they generate, leading to many economically important activities in civilian industry. Now the AEC is considering giving some emphasis to pinpointing the nonnuclear technical advances made in the course of its nuclear research and development.

The Clearinghouse for Federal Scientific and Technical Information is encouraging other agencies to provide it with copies of their research reports.

The editors of trade, technical, business, and professional publications must also be recognized for their extensive contributions to the location of new technology via continued fieldwork.

The combination of those efforts is beginning to create an environment for the recognition among innovators of the potential secondary importance of their work. But more is required. Perhaps a national policy encouraging the reporting of new unclassified technology generated with Government support would be helpful. There may also be a need to analyze and more specifically define the conditions under which limitations should be placed on the communication of unclassified information.[49] Government agencies should continue to be encouraged to declassify documents at the earliest time consistent with national defense considerations. And limitations on making documents available should be justified against a standard. Ideally, all agencies generating a significant amount of new technology might be encouraged to assign responsibilities for the identification of new technology to qualified and enthusiastic personnel.

Screening the Information. With apologies to Gertrude Stein (and dyed-in-the-wool documentalists), a document is not a document is not a document. The value of one piece of information is not necessarily equivalent to the value of another piece of information.

Because the library has often served as the model for technology transfer mechanisms, in many cases a considerable amount of straw must be waded through in search of the wheat. Too much straw in the diet discourages eating, and also makes for a lot of wasteful mastication. Burning the straw may not be wise since new uses for it may be found in the future. But it should not be served as the main course.

Screening means are required to find information of special significance and relevance and give it special emphasis, perhaps by calling it to the special attention of potential users.

In the process, information should not be discarded solely because it appears to have no practi-

[49] Of the total number of documents announced by the Defense Documentation Center in the 12 months ending July 1965, 47 percent were unclassified but limited; 32 percent were unclassified and unlimited; and 21 percent were classified.

cal value at present. It should be retained and categorized so that it can be retrieved at some future date. Some effort is being devoted in Government to this evaluative function.

NASA, for example, employs several private research institutes to evaluate innovations reported by the NASA technology utilization officers. Innovations deemed of special merit are given special emphasis by publication in the form of Tech Briefs and TU Reports.

The clearinghouse, with the aid of the Office of Technical Resources, screens incoming reports to find those of special significance, then calls attention to them via *Fast Announcements.*

The AEC holds conferences and undertakes programs to encourage the use of specially significant items such as its liquid zonal centrifuge.

But only a relatively small portion of the new technology generated through Government R. & D. is evaluated for transfer purposes. Certainly, some evaluation occurs outside Government. The trade magazine and the technical journal are screening mechanisms, and individuals who attempt to keep abreast of the unpublished advances in their fields do their own evaluating. But to ask each potential user to evaluate all new technology in his area is to waste a valuable economic resource—skilled manpower.

Other means are necessary. The originator of new knowledge might be encouraged to make a judgment of its utility. Perhaps professional societies and trade associations could assist in performing this function for their memberships. More specialized information centers might be created and, hopefully, paid for, at least in large measure, by the users to perform this task in given areas. Ideally, organizations whose members depend on knowledge of technological advances for their personal and professional well-being could perform the function.

The full burden of screening and evaluation should probably not be the responsibility of the taxpayer at large, since the benefits of the function seem to be spread too unevenly. Some form of cost sharing by the beneficiary is in order, although this does not mean, of course, that he must pay for the service directly. He can pay for it in his purchase of resulting services, such as membership in specialized information centers or regional service centers; by purchase of publications and announcement services resulting from evaluations; by normal support of his professional society or trade association; or via some other means.

Organizing for Retrieval. Few activities that appear so simple to the uninitiated are, in reality, as complex as the problem of arranging information in a manner that permits its easy retrieval for all relevant purposes—and for those purposes only.

Report titles are wholly inadequate as a basis for quick and accurate retrieval, since most titles are as definitive of a report's content as any of the proverbial descriptions the blind men gave after touching the elephant.

For example, consider the report title: Materials Investigation: SNAP/50 Spur Program Mechanical Properties of TZM.

The descriptive terms used to categorize the document for later retrieval were: molybdenum alloys, turbine parts, ductility, titanium alloys, carbon alloys, zirconium alloys, processing, forging, tensile properties, hardness, recrystallization, transition temperature, creep, microstructure, stresses, heat treatment, turbine blades, turbine wheels, gas turbines.

While the descriptors add many dimensions to the ability to retrieve the report, they admittedly exhaust only a small portion of words and phrases that might be used in posing a question for relevant information in the report while a system user involved in turbine design problems would readily retrieve the document from the system, the designer of a propeller shaft, for whom the information might be equally important, would have to phrase his question in terms other than product language. He would have to design a more imaginative search strategy in order to retrieve the document. Although not too much imagination would be required in this case, because the document is indexed under both "stresses" and "forgings," likely areas for the shaft designer to search, the problem is illustrated.

Thus indexing poses a major dilemma: Be conservative in the terms used and the document will not be found in many instances where it might be relevant; be liberal in describing the document and it will show up as an unwanted nuisance far too frequently.

Some solutions exist. One partial answer is the use of hierarchical description methods with considerable cross-referencing. Another is the development of multiple systems with separate sets of descriptors to serve different bodies of users with reasonably homogenous interests and language. The cost of operation of such systems is obviously expensive, but the economic feasibility of moving in that direction should be more fully explored. There are significant tradeoffs between the cost of performing the function and the time savings that would result from reducing the need to examine the abstracts of numerous unwanted documents, plus the advantage of retrieving a greater proportion of relevant information.

The entire question might be better analyzed if more research in the documentation field were performed from a user-oriented rather than source-oriented viewpoint.

The question of abstracting comes up in the same context. With most mechanized systems, and many manual systems, the seeker of information is supplied a set of abstracts as a result of an information search. Seldom would it be practical, under any conditions, to deliver a full set of documents. (The sheer awesomeness that would result from stacking 30 pounds of paper on a man's desk in response to an inquiry would defeat the utility of the system, let alone other obvious problems of logistics and cost.) The information seeker is then in a position of making his own evaluation, determining which documents he wants to examine in full, on the basis of the abstract. The degree to which the abstract mirrors the content of the document then becomes crucial. (Perhaps no one is better equipped to write an abstract than the author of the document, a function that should be and is being encouraged.)

The entire subject of organizing information for better retrieval demands continuing attention by imaginative researchers. Such work should be encouraged by the Government and private groups alike. Contributions to this area are being made from numerous quarters, public and private, including OSIS, AEC, NASA, NIH, and many others. But the problem deserves increased emphasis.

Attention to Significance. Earlier in this paper, the importance of incremental advances in technology was emphasized. The new lubricant formulation, the new circuit design, the new inspection technique, and the improved composite material, while having widespread potential utility, are rarely significant enough to start the technical grapevines buzzing. But incremental advances often deserve special communication, and consideration might be given to means of bringing them to the attention of potential users more rapidly on a selective basis.

Fast Announcements and Tech Briefs are two existing means of doing so. Others might be considered.

Soliciting the cooperation of specialized business publications in performing that function should be encouraged. A more rapid means of communicating such information to the correct audiences would be difficult to devise at low cost.

Knitting the Elements. Frequently, several seemingly unrelated advances that occur at about the same time derive special significance when examined in composite; the addition of a new item of information to a bank of other pieces of information can give the entire resource new significance. Related advances can occur in fields traditionally far removed from one another, such as a medical discipline and a subdiscipline of electronic engineering. This calls for switching mechanisms among information systems. In a few cases, specialized information centers perform such functions today. New methods must be found, including mechanical or electronic aids that will speed the process. Federal Government encouragement of research and exploration in this area is recommended.

Encouraging Use. Many who could benefit from technology transfer have yet to be exposed to the advantages. Many others, discouraged by attempts at earlier times when little could be done to assist them, must again be exposed.

Information is a marketable commodity if it meets certain tests, such as significance, currency, relevancy, ease of availability, and comprehensiveness. But few practitioners in information services or technology transfer programs employ a marketing approach. William Knox has urged:

> Let us look at information services as a business—a business with service as its product—not abstracts, not indexes, not books, but service . . . . Let us concentrate on the marketing side—too long ignored—not on the production side. The major attention and financial support given to hardware and information processing techniques indicates an overemphasis on production variables.
>
> Marketing information services in the way it should be done will probably not be easy. It will require new attitudes, new patterns of thought, new approaches—and new people. The record speaks for itself.[50]

What will be required on technology channeling mechanisms that can generate payment for value received? Several points are obvious:

(1) Information service and technology transfer people must recognize the existence of segmented markets. Tailored services must be proffered to definable groups and subgroups. Selective dissemination services will not be sufficient, though they represent a significant step forward. Needed will be better switching mechanisms, some thoughtful repackaging of information, better categorization at the input side and better "interest profile" building on the output side, better analysis of document content, more emphasis on interpretation of the "why" and "what it means" instead of the mere presentation of "what" and "when."

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[50] Knox, William T., "Marketing-Oriented Information Services," Speech at joint dinner meeting of the American Documentation Institute, American Medical Writers Association, Society of Technical Writers and Publishers, and Special Libraries Association, Washington, D.C., Mar. 15, 1965.

(2) Improved local access will likely enhance the marketability of information on new technology.

(3) Better referral services will be required; successful service organizations seldom tell their customers "no."

(4) More communicators, sociologists, and economists might be needed to add to the engineers, scientists, and documentalists that make up the full complement of know-how in many centers today.

(5) More effort will be expended to determine the real problems and objectives of a potential user of technical information, not just blind faith in what he feels to be his problems. Some imaginative effort to interest the potential user in new technology outside his stated sphere of interest, but within his reasonable sphere when viewed objectively, might also pay handsome dividends.

(6) Certainly we need to learn much more about how new ideas become accepted or rejected within organizations.

Joining Present and Future. The existence of some fragments of technology can and does encourage investment in the development of needed additions. But sometimes, after considerable development cost, it is discovered that someone else got there first. This should be avoided in the broad area of the public domain, if possible. Technology transfer implies not only the provision of what now exists but the indication of what factors are sure to bear upon it.

Permission to "Browse." Technology transfer is often looked upon as a problem-solving mechanism only. Certainly it is that, but it is also much more. It can be a means of bringing about ideas for the solution of problems not yet recognized and the meeting of objectives not yet defined. Bringing that about requires the development of methods that allow people to browse through the technology available, much as a do-it-yourselfer shops about in a hardware store or a reader scans the contents of a magazine.

Since the volume of information available demands the use of mechanized systems today, allowing for browsing must be brought about mechanically and electronically. A step in that direction will be the use of remote consoles tied to a central information bank on a computer time-sharing basis. Project MAC at MIT is the current pacesetter for systems of this type. NASA's Scientific and Technical Information Division is examining the feasibility of such a system on an experimental basis.

Meeting this requirement, as well as others, demands compatibility among information systems. COSATI should be encouraged to continue to strive for coordination of systems among Federal agencies. Efforts to make Government and private systems compatible must also be promulgated.

The Quality of Receivership. In terms of understanding how to create a climate for innovation, society today is long on theories and short on substantive knowledge. We may also be long on apathy.

But, as has been repeatedly emphasized, new technology seldom occurs in "off-the-shelf packages." Innovations originating in the military/space/nuclear realm generally require adaptation for use in other contexts. Sometimes, a higher order of innovation is required to make successful adaption than was needed to conceive the original advance, and the out-of-pocket costs can be high.

Obviously, there would be a high return on an investment that would in fact define the elements of a "creative climate," that would determine the characteristics that set the innovative person apart from others, or that would bring about an understanding of the essential ingredients of entrepreneurship.

Encouragement of research in the fields of focusing on those questions is recommended. Devising means of overcoming the barriers to technology transfer, and perhaps more importantly, determining how to provide incentives for the utilization of available technology are goals worth pursuing.

Personal Involvement. The written word is essential to technology transfer, but it is insufficient for effective transfer. Required is considerable personal involvement and person-to-person communication.

> The implications of a new technology in a variety of fields cannot be transferred by the written word. Some interplay between individuals is necessary to permit modification of the ideas of both the giver and the receiver in order to have a meshing of the proposals of each. Therefore, to increase the rate of technology utilization, a means must be provided to permit a meeting of qualified individuals. Publication is an important step in this process, but it is only the first step. Its primary purpose is to bring to the attention of the proper individuals the fact that certain information is available and to identify its source, thereby opening the way to subsequent communication between people with mutual interest. It is necessary to set up a system by which this can be accomplished and a special effort should be made to clarify the procedure to be followed.[51]

The Personal Champion. A wealth of experience on a variety of fronts documents the assertion that the odds on a technology being employed are greatly enhanced if it is championed by the inventor, the man who visualizes the application, an intermediary, the management of the firm that might use the concept, or by a person or group responsible for identifying and using new technology.

[51] *Transference of Non-Nuclear Technology*, etc., *op. cit.*

A company employs purchasing agents to seek out, evaluate, and bring in the optimum materials and supplies. Why not then new technology agents to seek out, evaluate, and bring in the best and most useful new knowledge? These technology agents would be unusual people to whom an air-travel card and a telephone would be far more important than an office and desk. They are generalists with a technical bent, but not necessarily engineers or scientists. They understand the arithmetic of business but are not accountants or mathematicians. They are imaginative and can readily grasp new concepts. They are fully informed on their company's manufacturing capabilities and marketing objectives. They are outstanding communicators, know how to sell ideas, and are capable of dealing effectively at all levels inside and outside the firm. They know how to attach themselves to the industrial, governmental, and professional grapevines that bear the fruits of knowledge most important to their companies. These technology agents are really technoeconomists and sociotechnologists.

Effort should be expended in both the private and public sectors to find men with the required capabilities and interests to perform these functions. Organizations seeking to benefit from the results of Government R. & D. should also determine whether their organizational framework is designed to permit the ready inflow and acceptance of technology generated outside the firm.

APPENDIX A

Examples of Use of NASA/AEC Technology

Problem with Metal Porosity

A large utility corporation, doing research on advanced power-conversion methods, found itself stymied with a problem in metal porosity. It reported this to a NASA regional dissemination center, which was able to supply information that, although developed by NASA for a different purpose, solved the utility's problem. Its board chairman stated that the potential of this one transfer can be predicted as having multimillion-dollar value when the new power-conversion method is introduced commercially.

Refractory Metal Purification Techniques

Requirements arising from basic research for exceptionally pure materials resulted in the development by AEC contractors of new techniques for the purification of tungsten, tantalum, and columbium. These newly developed techniques are now being applied throughout the metals industry.

Welding Thin Metal

A manufacturer was using soldering to join metal parts only 0.004-inch to 0.006-inch thick. A retrospective search of the NASA information system suggested the possibility of using the TIG (tungsten-inert-gas) process. After experimentation and testing, the company introduced the process into its production line. Benefits include elimination of several components, significant man-hour savings, an extension of the usable temperature range of the part, and an inhouse production capability for parts that were previously purchased.

High-Current Switches

The need to switch currents in the multimillion-ampere range in the AEC controlled-fusion program has brought about the development of fast, high-current switches that are now being used in plasma experiments, magnetohydrodynamics, and other applications. General Electric is now marketing an entire line of ignition switch tubes that are based upon developments arising from the controlled-fusion program.

Biotelemetry System

A compact biotelemetry system was originally developed under NASA sponsorship to monitor astronauts during actual and simulated space flight without encumbering leads or bulky amplifying equipment. A large company is now marketing it as a cardiac monitoring system for use in hospital intensive-care wards.

Laminar-Flow Clean Rooms

In 1960 the AEC filed for a patent on a laminar-flow clean room developed by the Sandia Corp. Since then a new industry has come into being to meet the demand for laminar-flow clean rooms and work stations. Some 30 manufacturers are active in supplying laminar-flow equipment, and thousands of clean work stations have been installed. They are of value for such nonnuclear purposes as hospital operating rooms and the manufacture of precision equipment.

Uprated Rectifier

A company produced a silicon-controlled rectifier having a turnoff time of approximately 100 microseconds. It learned of a document in the NASA information system describing several ways by which the turnoff times of silicon-control rectifiers could be modified. By experimenting with the techniques described, the company was able to develop rectifiers having turnoff times down as low as 50 to 60 microseconds, making the device usable over a wider frequency range. The company estimates that independent research to produce these results might have taken its engineers several months; with the information, its tests were completed in 2 days.

New Superconducting Alloy

The columbium-zirconium alloy that is now being widely used in superconductor applications was discovered in the course of an AEC-sponsored program. It was found that metallurgical variables, such as prior working history, impurity content, and heat treatment, have major effects on superconducting properties. It was also found that precipitation heat treatment at 800° C resulted in a tenfold increase in the critical current density of high-field superconductors. This increased current density is vital in such applications as high-field solenoids, thermonuclear plasma containment, space screening, friction-free gyroscopes, and loss-free power transmission. Superconductors made by these techniques are being marketed by several companies.

Alkali Silicate Paint

A special paint formulation was developed by the Goddard Space Flight Center for use on earth satellites to aid in thermal control and to protect them from particle bombardment and other environmental hazards. Several paint manufacturers have developed variant formulations that show exceptional resistance to high temperatures, thermal shock, and abrasion. Applications range from durable coatings for calcining kettles to protection for automotive exhaust systems.

APPENDIX B

Brief Reviews of Technical Information Programs of Selected Federal Agencies

A large number of Federal agencies, offices, and bureaus that conduct, foster, and/or support research and development programs have technical information activities.

This appendix gives brief descriptions of the technical information programs of a random sampling of such agencies. It is possible that, due to an interest in brevity, the descriptions here do not fully define or describe the total informational activities of the organizations represented. The purpose of this appendix is simply to alert the National Commission on Technology, Automation, and Economic Progress to the fact that an extremely large amount of scientific and technical information is available, in one form or another, to support an effort to channel new technologies in promising directions.

U.S. Coast Guard

The Coast Guard conducts research, testing, and development associated with all phases of Coast Guard activities: civil engineering; electronic engineering. Information on this research is reported in testing and development division reports (approximately 40 annually), civil engineering reports (approximately 60 in existence to date), electronic engineering station project reports (approximately 40 issued annually). Existence of these reports is announced in bimonthly *Engineers Digest*, the *Technical Abstract Bulletin*, and in the *Monthly Catalog of Government Publications*. The Office of Engineering of the Coast Guard distributes approximately 1000 copies of the above-listed reports to individuals, universities, and various industries in the maritime business, upon their specific request. However, all of the above-listed publications are also available from the Superintendent of Documents. Therefore, the Coast Guard is not able to give an exact figure as to the volume of distribution of their reports.

The Coast Guard serves as secretariat for the Interagency Ship Structures Committee. Presently, about 170 reports have been published by this committee. Reports are sent to a mailing list of individuals, universities, and industrial concerns, the total mailing list numbering about 400. Requests outside the mailing list are honored but rarely come from someone outside of "the professionals."

The Coast Guard publishes the *Annual Report of the International Ice Observation and Ice Patrol Service in the North Atlantic*. The Coast Guard distributes this report to about 800 nonprofit organizations in all nations participating in the International Conference on the Safety of Life at Sea.

The Floating Units Division of the Coast Guard gathers data on weather, oceanographic, and communications data as a service for other Government agencies. The data is analyzed and published by the cognizant agency.

The Coast Guard is a member of the Interagency Committee on Oceanography which currently has approximately 18 publications available. The distributing agency for these reports within the U.S. Government is the Navy Department.

Bureau of Customs

The scientific activities of the bureau are centered on furnishing technical information to customs officers covering the analysis, sampling, weighing, and gaging of imported and exported merchandise. As a general rule, methods of analysis used by the Bureau of Customs are not published. Technical information is not widely distributed because it contains a large amount of proprietary industrial information. However, there are a few publications available: 42 circular letters have been published; 177 U.S. Customs Laboratory methods manuals have been published. Publications available can be obtained on written request if it is determined by the

Bureau of Customs that the requestor should have the information in question. The existence of the Bureau of Customs publications is not announced in any of the standard Government announcement bulletins.

U.S. Geological Survey

The Geological Survey conducts research in geology, water resources, conservation, and topography. Results of the Survey's work are published as (*a*) books and (*b*) maps and charts. Book publications can be divided into the following categories: bulletins, which are published at the rate of 100 annually; water supply papers, which are published at the rate of about 100 annually; professional papers, which are published at an annual rate of 100; circulars, which are published at an annual rate of about 15. Book publications are announced in the monthly *New Publications of the Geological Survey* which is mailed to a list of 12 000. All book publications are announced as available from the Superintendent of Documents. The Survey retains only a few copies for distribution to individual requestors. In addition, the Survey purchases from the Superintendent of Documents 500 copies of any publication to mail to those libraries which participate in the library exchange program of the Survey. Those 500 libraries are located throughout the world and in principle have a copy of each technical publication of the Survey. These copies are available for microfilming by potential users. Maps and charts prepared and printed by the Survey are available for purchase from the Survey, one of its field offices, or from one of the Survey's authorized map agents (commercial). Maps are sold in an annual volume of approximately 6 600 000. Certain unpublished data (Parex. Stream Flow, Ground Levels) is available upon request from the Survey's headquarters office. Such data is usually published annually. Inquires of a general nature are also answered on an individual basis by one of the seven field offices of the Survey which have public inquiry offices.

Bureau of Mines

The Bureau conducts research in the following areas: safety conditions in mines; metallurgy; mining; nonmetallic minerals; fuels technology; explosive technology;

and helium. The Bureau publishes the results of its research in the following types of publications:

1. *Bulletins*—which come out at the rate of about 10 annually, over 600 titles now being available in the series. New reports are disseminated by the Bureau to a selected mailing list. The size of the mailing list varies with the particular bulletin in question but it usually contains 300 to 400 names. Individual copies may be purchased from the Superintendent of Documents. No data is available on the number of copies of bulletins distributed annually because the Bureau has no control on the number of documents distributed by the Superintendent of Documents.

2. *Reports of Investigations.* This type of report covers a smaller field of technical inquiry than bulletins. They are published at a rate of 200 annually. The Bureau distributes copies to a selected mailing list of interested parties; the mailing list usually includes about 300 names. Individuals are able to purchase copies of these reports from the Superintendent of Documents.

3. *Information Circulars.* These circulars contain much marketing and economic data. They are published at a rate of about 200 per year. Circulars are distributed to a selected mailing list of individuals numbering around 200. Individual requests are sent to the Superintendent of Documents. In addition to the above list of reports, various handbooks and pamphlets are available from the Bureau of Mines. Mineral industry surveys are prepared and are mailed to a selected list of industry specialists. This list numbers about 200. Bureau personnel publish about 500 to 600 papers a year in various journals and other professional publications. Bureau publications are announced by means of a *Monthly List of New Publications* which is mailed to those on the Bureau's mailing lists.

Office of Coal Research

The Office of Coal Research conducts a program of research and development designed to increase the value of the coal industry to the Nation's economy by better and more efficient methods of mining, preparation, and utilization of coal. All of this Office's research and development work is done under contract.

Fifteen scientific and technical reports have been published so far as a result of research and development work supported by this Office. (This Office was established in 1960.)

These reports are distributed in one of three ways: by the Federal Clearinghouse from mailing lists of approximately 600 individuals, universities, and industrial concerns, the mailing lists having been supplied to the Clearinghouse by the Office of Coal Research; by the Office of Coal Research through a specialized mailing list of individuals, universities, and industrial concerns. These mailing lists are directed to those groups who might be interested in a particular publication. The Office of Coal Research also distributes copies of their reports in response to individual requests; companies working under contract to this Office are urged to make distribution of reports on their contract R. & D. work to others in the coal business.

Federal Communications Commission

The FCC conducts a limited research, development, and testing program related directly to the field of telecommunications and its obligations to serve as a regulatory body in that area.

Technical publications of the FCC include: *research reports*—reports on technical communications subjects which are produced at an annual rate of 10 a year; *technical information bulletins*—catalogs of acceptable communications equipment which are updated periodically. All publications may be obtained by writing directly to the FCC, Office of the Chief Engineer.

Federal Aviation Agency

The FAA conducts research in the fields of aviation medical service, air traffic control, weather, and aircraft safety. Presently, the FAA is also reporting specialized R. & D. efforts in connection with the development of a supersonic transport.

Reports resulting from R. & D. supported by the FAA include: *Research and Development Progress Report,* which is an annual publication available from the Superintendent of Documents; and *Technical Reports,* which are published at an annual rate of about 250.

All of FAA unclassified material is disseminated to the scientific community through the Federal Clearinghouse. In addition, NASA and DOD (DDC) receive a copy of each technical report published by FAA (classified and unclassified) for their scientific and technical information retrieval systems. Technical reports on the development of the supersonic transport are handled by NASA and the DDC.

Bureau of Reclamation

This Bureau conducts research in the following areas: chemical engineering; concrete technology; hydraulics; soil mechanics and foundation engineering; geology; and other phases of water resources development.

The Bureau publishes many documents containing technical information, but the most widely used reports are *Engineering Monographs* and *Technical Reports.*

1. *Engineering Monographs* are now disseminated from Washington at the rate of about 15 000 copies per year. There are 34 different monographs now available for distribution.

2. *Technical Reports* are distributed for the Bureau by its Denver Research Center. There are approximately 200 reports available covering about 6 categories of research. The volume of annual distribution is close to 25 000 documents.

Publications are distributed upon request to those individuals, scientists, engineers, universities, and industrial labs on the mailing list of the Bureau to receive technical documents. The mailing list for *Engineering Monographs* is maintained in Washington and numbers about 12 000.

Office of Saline Water

The Office of Saline Water carries out its research and development program relative to the improvement of existing conversion processes and the development of ideas and data for new processes. The results of this Office's research and development efforts are published in various media. Technical reports were being published at the rate of 7 per year in 1961 but 100 were published in 1964. The Office now has available one consolidated published bibliography of material available on saline water research. This is available upon request to the Superintendent of Documents. The Office of Saline Water also makes available proceedings and papers of various symposia and conferences on saline water upon receipt of an individual request.

By far, the greatest number of documents distributed are the technical reports. Until early this year, the Office distributed some of its publications, the bulk being distributed by the Federal Clearinghouse in Springfield, Va. Now, however, publications are distributed by the Superintendent of Documents upon request to that office. Any inquiries received by the Office of Saline Water for their consolidated bibliography or for technical reports are referred to the Superintendent of Documents.

Defense Documentation Center

One of the larger handlers of scientific and technical information, the Defense Documentation Center (DDC) services the information needs of the entire defense community.

Documents flow into DDC at a rate in excess of 200 per day. For example, the agency processed 5040 documents in May 1965, 4200 in June, and 4530 in July.

On the output side, DDC services document requests at a daily rate in excess of 5500. For example, in April, the facility processed 125 000 requests; in June, 137 000; in July, 119 000. In the 12 months ending April 1965, it processed 1 200 000 requests for documents (versus 953 000 in the preceding 12-month period). During calendar year 1965, the agency expects to handle 1.7 million document requests.

(The totals include requests for unclassified and unlimited documents, which are passed along to the Clearinghouse for Federal Scientific and Technical Information, which services those requests under interdepartmental agreement.)

In addition, DDC prepares bibliographies for qualified requestors.

As of January 1, 1965, there were 3700 military organizations, 300 other Federal agencies, and 2000 industrial and educational concerns registered for DDC services.

Twice a month, the center publishes its announcement journal, *Technical Abstracts Bulletin* (TAB), and the *TAB Index*. Cumulated indexes are also provided.

Documents are microfilmed.

Local accessability to the document collection is provided through regionally deployed field services which have facilities for search, on-the-spot review, and printouts of selected pages.

The Defense Documentation Center had its origin in July 1945 when literally tons of captured German and Japanese technical documents were added to the mass of domestic R. & D. reports generated by World War II, and the Army Air Force established an Air Documents Research Center. With the separation of the Air Force from the Army, the Air Force and the Navy combined to form the Central Air Documents Office (CADO). Two years later, the Army agreed to participate in CADO.

On May 14, 1951, Secretary of Defense George C. Marshall established the Armed Services Technical Information Agency (ASTIA), to serve all three military departments and their contractors. CADO and the Navy Research Section of the Library of Congress were incorporated to form ASTIA. ASTIA started with a collection of some 400 000 titles and received requests for 40 000 documents the first year. ASTIA continued until March 19, 1963, when the agency was reconstituted as DDC. At that time ASTIA had a collection of nearly 700 000 titles and its annual requests for documents totaled more than a million. After 18 years of Air Force operational control, the functions performed by DDC were transferred to the Defense Supply Agency in November 1963. The DDC collection, which now totals nearly 750 000 reports, spans the scientific spectrum from astronomy to zoology.

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